PAYMENT FOR ECOSYSTEM SERVICES AND SOIL HEALTH WORKING GROUP FINAL REPORT

Prepared for the Vermont General Assembly in Accordance with

Act No. 83, Section 3 (2019)

Act No. 129, Section 24 (2020)

Act No. 47, Section 3 (2021)

Submitted to the

Senate Committee on Agriculture

House Committee on Agriculture, Food Resiliency, and Forestry

By the

Vermont Agency of Agriculture, Food and Markets

January 15, 2023

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I. Executive Summary

This report fulfils the requirements of Act No. 129 (2020) and Act No. 47 (2021) that the Secretary of Agriculture, Food, and Markets shall submit a report to the Senate Committee on Agriculture and the House Committee on Agriculture and Forestry on behalf of the Payment for Ecosystem Services and Soil Health Working Group (the Working Group) on or before January 15, 2023.

Over three years, the Working Group developed a vision for a payment program which will increase carbon storage, nutrient, soil, and stormwater retention, water quality outcomes, and the ability to support biodiversity, thus improving the health of the broader ecosystem for all Vermonters while also supporting the economic health of Vermonters engaged in agriculture.

The Working Group recognizes that Vermont farmers can make (and are already making) substantial contributions to water quality through adopting agricultural conservation practices across their farm. Many of these water quality conservation practices also provide a co-benefit of improving soil health metrics.

The Working Group's goals for this program are to:

- Compensate farmers for providing clearly defined ecosystem functions.
- Ensure that metrics and associated compensation are clearly and directly linked to the specific, quantifiable outcomes.
- Include farms of diverse types and sizes, including those currently and historically underserved by payment programs.
- Be efficient with time and funding to ensure that a high return is provided to the farmer and society.
- Continually improve both research and the program to support agricultural innovation, adaptative management and development of new practices and tools.

The Working Group also explored where on the farm action might be taken. For guiding an initial program, the Working Group concluded that the program should reflect a whole farm approach, focusing first on outcomes in the soil, in the field, and at edge-of-field while considering outcomes in other parts of the farm where possible.

The Working Group agreed that all farmers should be eligible to participate if they are in good standing with the Secretary of Agriculture, Food, and Markets as defined under 6 VSA § 4802(3). However, only those farmers who meet the standards and requirements set by the program will receive payments.

The Working Group explored ten potential approaches for a program. Five of these approaches were develop for the Working Group by the Agency of Agriculture, Food, and Markets (AAFM) based on goals and priorities of the Working Group, three program proposals were led by three farmers (one of whom is a Working Group member), and two are existing programs developed previously by AAFM and the Vermont Agricultural Water Quality Partnership (VAWQP).

The proposals were as follows:

1. *CSP+*, proposed framework presented by Guy Choiniere, Jennifer Byrne, and Christopher Bonasia
2. *VT PES Observed Metrics Approach*, proposed framework presented by Scott Magnan
3. *VT Healthy Soil Protection & Restoration Act*, proposed framework presented by Stephen Leslie[1]
4. *The Vermont Environmental Stewardship Program (VESP)*, existing framework managed by AAFM[2]
5. *The Vermont Pay for Performance Program (VPFP)*, existing framework managed by AAFM

[1] The technical services task 6b report (under Appendix Q) contains details for the three farmer-led proposals (1-3).

6. *Soil health testing via Cornell Comprehensive Assessment of Soil Health (CASH)*
7. *Soil carbon testing via soil bulk density tests*
8. *Soil carbon modeling via a process-based model*
9. *In-field observation with modeling assessment and payment*
10. *In-field observation with rubric-based scoring*

Following extensive deliberation, the Working Group selected an idea first proposed by a group of small farmers to supplement payments to farmers in Vermont who enroll in the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)'s Conservation Stewardship Program (CSP).

CSP is 'threshold' based performance program which assesses a farm's whole area of management – including cropland, pasture, headquarters infrastructure, and associated ag land such as riparian buffer zones – against national NRCS environmental standards. Farms which exceed these national targets, and agree to implement conservation practice enhancements in each type of land they manage, are eligible for five years of annual payments through CSP. CSP is the nation's largest conservation program by acreage, though it is the least popular NRCS conservation program for farmers in Vermont. Pairing the Working Group's PES Pilot with USDA NRCS CSP will leverage existing federal resources and support an ecosystem services payment program that is based on whole-farm conservation performance.

The Working Group's Payment for Ecosystem Services Pilot Program was discussed to have the title: Vermont Farmer Ecosystem Stewardship Program. This program will be a pilot program that will supplement CSP payments to new enrollees with flat-rate lump sum payments at specific points in the CSP planning and contract process:

1. A **Planning Completion Payment (PCP)** upon completion of conservation assessment and planning with a CSP planner.
2. An upfront **Contract Incentive Payment (CIP)** upon signing of a 5-year agricultural CSP contract.
3. An upfront **Practice Incentive Payment (PIP)** will also be awarded to those farmers signing the 5-year CSP contract to support implementation of enhancement practices needed to meet CSP standards.

In addition, producers who, at time of pilot program rollout, are already enrolled in an agricultural CSP contract will be eligible for a one-time supplemental payment that mirrors the PCP and CIP payments new enrollees will receive to support their continued implementation of their contracts.

In addition to financial incentives for engaging in planning and contracting with CSP, additional technical assistance support will be made avaliable to farms through the retention of a qualified contractor to provide CSP conservation technical assistance.

These payments interventions were identified by the Working Group as areas of existing bottleneck that have proven to be historic obstacles to farmers enrolling in the CSP program. While CSP can be beneficial in the out years, there is significant upfront planning and costs that a farmer much shoulder before seeing renumeration. The PES pilot program recommended by the Working Group seeks to strategically inject financial assistance payments to support the necessary planning and implementation necessary for farms to achieve CSP stewardship thresholds and successfully participate in five years of conservation practice implementation.

There are several advantages to this approach from the Working Group's perspective:

1. The Vermont Farmer Ecosystem Stewardship Program leverages an existing program that focuses on incentivizing environmental stewardship and the provision of ecosystem services.
2. The higher state-supplemented base payment will incentive greater CSP participation and thus greater stewardship. The Working Group heard from several producers with farms of diverse

sizes and crop types who are currently enrolled in CSP that the program is valuable to them, but that the low base payment is an insufficient incentive for enrollment and that the amount of planning needed is a barrier to even applying for the program.

3. CSP allows farmers to pick from several conservation enhancements that are required to be implemented for CSP participation to improve resource concerns areas, allowing farmers to decide the approach that would work best for them and their farm.
4. The state-supplemented upfront payment provides support to farmers to undertake the initial planning, which has been named as a barrier to higher participation in the program.
5. The upfront state payment on top of the annual payments from NRCS will provide farmers additional capital to implement their conservation enhancements.
6. The state PES pilot would fund additional one-on-one support and technical assistance from planners for clients and potential clients. The Working Group heard that the current availability of technical assistance to support enrollment in CSP would benefit from being bolstered.

Ultimately, the Vermont Farmer Ecosystem Stewardship Program pilot should lead to: 1) higher enrollment in CSP; 2) greater farm viability given payments from both state and federal funds to farmers; 3) enhanced conservation practices and activities; and 4) enhancement of ecosystem functions, including but not limited to increased carbon storage, nutrient, soil, and stormwater retention, and the ability to support biodiversity.

The Working Group also learned from several of its members and other stakeholders that navigating the range and variety of state and federal funding programs can be a challenge for farmers who seek to leverage these opportunities. The Working Group subsequently identified several potential actions to ameliorate this complexity, including farm teams, a web portal, and a potential soil health trust.

Working Group members explored methods for measuring soil and other on-farm biodiversity and interpreting metrics. The Working Group believes that resources should be committed toward researching approaches to measuring biodiversity and interpreting metrics, particularly around translating qualitative observations into robust quantitative metrics.

Lastly, the Working Group as it concluded its work identified several lessons learned, both in terms of substantive tradeoffs and challenges of creating a program and of the Working Group's process itself.

II. Legislative Background and Charge

Enabling and Amended Legislation

Due to the initiative of three farmer-led watershed coalitions, the Vermont Legislature enacted Act No. 83 of 2019, Sec. 3 which was signed into law by Governor Phil Scott on June 20, 2019. That Act charged the Secretary of Agriculture, Food and Markets to convene a Soil Conservation Practice and Payment for Ecosystem Services Working Group.

Act No. 83 of 2019 charged the Working Group to:

1. identify agricultural standards or practices that farmers can implement that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters;
2. recommend existing financial incentives available to farmers that could be modified or amended to incentivize implementation of the agricultural standards identified under subdivision (1) of this subsection or incentivize the reclamation or preservation of wetlands and floodplains;
3. propose new financial incentives, including a source of revenue, for implementation of the agricultural standards identified under subdivision (1) of this subsection if existing financial incentives are inadequate or if the goal of implementation of the agricultural standards would be better served by a new financial incentive; and

4. recommend legislative changes that may be required to implement any financial incentive recommended or proposed in the report.

Between September 2019 and January 2020, the Working Group met in-person five times and held six webinars with experts and practitioners who provided resources and perspectives to aid in the Working Group's thinking about tools, metrics, and system design for payment for ecosystem services (PES) programs. The Working Group submitted a Report to the Legislature on January 15, 2020, which satisfied the requirements under Act No. 83 of 2019. This report concluded that more time and expertise was needed for the Working Group to review and recommend an agricultural PES program for the State of Vermont which satisfied the goals of the farmer watershed coalitions which raised the need for a new PES program in Vermont.[3]

Following several recommendations of the Working Group, as laid out in its 2020 Report, Act No. 129 of 2020 amended Act No. 83 of 2019 to rename the group the "Payment for Ecosystem Services and Soil Health Working Group" (PES WG), to establish the Working Group through February 1, 2022, to include additional seats on the Working Group, and to lay out additional charges for the Working Group.

In Act No. 129 of 2020, the Legislature instructed the Secretary of Agriculture, Food and Markets to submit a report that shall include the following recommendations and analysis:

1. a recommended payment for ecosystem services approach the State should pursue that benefits water quality, flood resilience, and climate stability, including ecosystem services to prioritize and capital or funding sources available for payments;
2. a recommended definition of healthy soils, a recommended method or systems for measuring soil health and other indicators of ecosystem health, and a recommended tool for modeling and monitoring soil health;
3. a recommended price, supported by evidence or other justification, for a unit of soil health or other unit of ecosystem service or benefit provided;
4. proposed eligibility criteria for persons participating in the program;
5. proposed methods for incorporating the recommended payment for ecosystem services approach into existing research and funding programs;
6. an estimate of the potential future benefits of the recommended payment for ecosystem services approach, including the projected duration of the program;
7. an estimate of the cost to the State to administer the recommended payment for ecosystem services approach; and
8. proposed funding or sources of funds to implement and operate the recommended payment for ecosystem services approach.[4]

Since receiving these additional charges, the Working Group met thirty-one times to review approaches to approaches to paying farmers for good stewardship of ecosystem functions and soil health and design a pilot program.

The Working Group met fourteen times in calendar year 2021 to advance work in preparing the findings and recommendations above. These meetings took place remotely via the 'Zoom' platform. On February 2, 2021, AAFM retained the consulting and facilitation services of the Consensus Building Institute (CBI) to provide facilitation services for the Working Group. These facilitation services were extended through 2022 with a contract which was amended on February 18, 2022.

At the direction of the Working Group, AAFM contracted with a team of technical experts led by the University of Vermont (UVM) Gund Institute for the Environment. The purpose of this contract was to provide technical research and analysis services to the Working Group. The initial technical contract with UVM was executed on September 29, 2021 and amended on June 30, 2022. The technical contractors

[3] The Working Group's 2020 Report to the Legislature is included as Appendix C.
[4] 2020 Acts and Resolves No. 129, Sec 24 §§(d)(1) – (8)

produced ten task and subtask reports in collaboration with the Working Group. These reports can be found in the Appendix of this report. The titles of the reports are as follows:

1. Measuring ecosystem services for soil health
2. Field scale soil health scenarios

3a. Results of the 2022 Vermont farmer conservation & payment for ecosystem services survey
3c. Farmer perspectives on administrative burdens & potential compensation structures
4a. Calculating the full economic costs of selected field management change scenarios for improving soil health on Vermont farms
4b. Economic cost of scenarios 1-3
4c. Economic cost of scenarios 4a-c

5. Valuation of ecosystem services from soil health

6a. Review of PES programs
6b. Farmer PES program proposals

7. Approaches to quantification of climate regulation ecosystem services at the whole farm scale
8. PES program design issues and recommendations[5]

Act No. 47 of 2021 extended the Working Group's charge through February 1, 2023. The Working Group thus submitted an Interim Report to the Legislature on February 1, 2022.[6]

The Legislature appropriated up to $250,000 for program development and $1,000,000 for establishing an initial program. Act No. 9 of 2021 appropriated $250,000 to AAFM for continuation of work in soil conservation practices and payment for ecosystem services which included the costs of the Working Group initially established by Act No. 83 of 2019.[7] Act No. 185 of 2022 (the fiscal year 2022 budget) further appropriated $1,000,000 to AAFM "for the development of an agricultural Payment for Ecosystems Services Program to support the work of the Payment for Ecosystem Services and Soil Health Working Group (PES WG) – as authorized by 2019 Acts and Resolves No. 83, amended by 2020 Acts and Resolves No. 129 and 2021 Acts and Resolves No. 47 – to enable Payment for Ecosystem Services Program development to retain facilitation services, contract identified research needs, fund pilot program development, and deliver payments to farmers for quantified ecosystem services." Details of the Working Group's proposal for spending the $1,000,000 appropriation are outlined later in this Report under Chapter X.

In calendar year 2022, the Working Group met fourteen times via Zoom and once in-person to advance its findings and recommendations under its legislative charges and to explore options and prioritize a specific approach for a pilot program. The Working Group also met twice in 2023 to finalize both its pilot approach and this Report.

Responses to Original Legislative Charges

In preparation for developing the recommendations as outlined under Act No. 83 of 2019, the Working Group further explored two key charges of Act No. 129 of 2020. These are both discussed briefly below.

1. *identify agricultural standards or practices that farmers can implement that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters;*

The Working Group drew upon AAFM's expertise to identify the existing practices that Vermont farmers can utilize to produce the ecosystem services of interest. AAFM developed and provided the Working

[5] These reports are included under Appendices I-S.
[6] The Working Group's 2022 interim report is included as Appendix D.
[7] 2019 Acts and Resolves No.9 Sec. 22 § (b)(3)

Group with an extensive matrix of practices approved by NRCS. These practices have been and evaluated nationally to indicate their conservation value.[8]

As the Working Group reviewed these practices, they noted that several agroforestry practices which might help produce the desired Ecosystem Services (ES) were not approved as a conservation practice standard through NRCS. In part, this led to discussions with NRCS and to provide for these additional practices in Vermont. In 2021, NRCS-VT adopted Conservation Practice Standard 381: Silvopasture as an eligible conservation practice for Vermont farmers to implement through the Environmental Quality Incentives Program (EQIP). This now means a comprehensive suite of nationally available agroforestry practices appropriate for Vermont are avaliable for Vermont farmers to implement through NRCS programs. These practices include windbreaks, riparian forest buffers, silvopasture, alley cropping, and forest farming.

2. *recommend existing financial incentives available to farmers that could be modified or amended to incentivize implementation of the agricultural standards identified under subdivision (1) of this subsection or incentivize the reclamation or preservation of wetlands and floodplains;*

The Working Group also received several presentations on financial incentives under existing federal and state programs focused on wetlands and floodplains. These programs aim to not only reclaim or preserve wetlands and floodplains but also to incentivize practices and actions on aspects ranging from soil health to aquatic and terrestrial biodiversity.[9]

Several members of the Working Group and members of the public raised the concern about the sheer number of programs available to farmers for conservation. The immense number of programs has the potential to produce inefficiency for farmers, technical service providers, and the public. It should be noted that this is not an uncommon challenge across states. For instance, the Lancaster County Clean Water Partners commissioned an extensive catalogue of existing partners and programs for clean water alone available to the agriculturally rich Pennsylvania County and identified 49 separate funding sources.[10] In a more local example, Franklin County Natural Resources Conservation District recently published a guide listing grant programs available to Vermont farmers which runs to 80-plus pages.[11]

Ultimately, all appropriated conservation program funding is obligated to farmers through state water quality and federal USDA NRCS programs on a year-on-year basis. Each year, millions of dollars of applications remain unfunded. In total, between SFY 2016 and SFY 2021, AAFM invested $32.4 million in clean water projects on Vermont farms, leveraging $18.9 million of federal investment and $7.2 million of farmer investment.[12] While some Working Group members remain concerned about the sheer number of programs, state and federal agencies point out that they have developed specific targeting of programs and priorities that require a service-delivery model that is not one-size-fits-all. Farmers' success in applying, contracting, and implementing these conservation programs is evidenced by the over 300,000

[8] Judson Peck, Sonia Howlett, and Alex DePillis, 'Existing Agricultural Programs: CO2 Emission Reduction / Mitigation Impact' (Vermont Agency of Agriculture, Food, and Markets, 2021), https://agriculture.vermont.gov/sites/agriculture/files/Water%20Quality/Payment%20for%20Ecosystem%20Services/Inventory%20-%20Existing%20Agricultural%20Programs%20-%20VCC%20Ag%20%26%20Ecosystems%20Subcommittee.xlsx.
[9] Copies of these presentations can be found at: https://agriculture.vermont.gov/pes/past-meetings.
[10] Lancaster Clean Water Partners, 'Collective Action for Clean Water: A Partners & Resources Inventory, Analysis, and Recommended Integrated Funding Delivery Strategy for Lancaster County' (Penn State Agriculture & Environment Center, March 2021), https://lancastercleanwaterpartners.com/wp-content/uploads/2021/04/Lancaster-Clean-Water-Partners-and-Resources-Inventory-March-2021.pdf.
[11] Franklin County Natural Resources Conservation District, 'Guide to Assistance for Agricultural Producers of Vermont: A Comprehensive Guide to Assistance Opportunities for Agricultural Producers of Vermont', 22 December 2022, https://www.franklincountynrcd.org/agproducersguide.
[12] Vermont Agency of Agriculture, Food, and Markets, 'State Fiscal Year 2021 Annual Report on Financial and Technical Assistance for Agricultural Water Quality', 15 January 2022, https://legislature.vermont.gov/assets/Legislative-Reports/AAFMFY21ReportonFinancialandTechncialAssistance.pdf.

acres of annual conservation practices that Vermont farmers implemented under state and federal water quality programs between SFY 2016 and SFY 2020.

Nonetheless, Working Group members remained concerned about the abundance of existing programs and expressed a desire to build on rather than compete with existing programs. As a result, the Working Group ultimately recommended a pilot which would leverage CSP – an existing federal program. Chapter VII of this report outlines the recommended pilot approach. The recommendation is informed by the Vermont Environmental Stewardship Program (VESP), which leveraged the assessment tool which undergirds CSP conservation assessment to recognize farmers for ecosystem stewardship.

While it was not named explicitly under its charges, the Working Group also heard proposals to enable farmers to better navigate the plethora of conservation programs available. The Working Group recognizes that each state or federal program has its own statutory or other regulatory requirements and complexities. The State would have far more control over consolidating, integrating, or simplifying its programs if the Legislature were to decide that such actions have merit. Many state programs supplement or are otherwise linked to USDA NRCS programs. These programs operate nationally, which makes it difficult for a single state to influence, shape, or consolidate them. Furthermore, Vermont has farms of diverse types and sizes with various needs which one or a few programs cannot easily serve. The Working Group recognized that technical assistance is essential to program service delivery and was made aware of the breadth of technical assistance provided to farmers in the state. State funds support much technical assistance through vehicles like the Agricultural Clean Water Initiative Program which has provided $11 million in program and organizational development funding for partner and farmer organizations since State Fiscal Year 2016.

Nonetheless, Working Group explored several ideas that might aid and simplify farmer navigation of programs and funding sources. These are expanded upon under Chapter XII of this report *Additional Considerations*.

III. Concepts of and Concerns about Payment for Ecosystem Services

The Working Group spent extensive time seeking to understand how the concept of ecosystem services and payments for ecosystem services (PES) might be applied in Vermont. The following sections describe this learning and articulate significant concerns about PES as programmatic paradigm. Ultimately, as articulated later in this Report, the Working Group moved away from a sole PES paradigm to a more whole-farm, farmer-led, supplemental program to existing state and federal programs.

What are the limitations of payment for ecosystem services?

Since submitting its report to the Legislature in 2020, the Working Group has had opportunities to further understand PES as a framework as well as the limitations of a PES framework for a program in Vermont. PES as a formal concept is a transactional relationship between ecosystem service producers and one or several buyers. The Working Group learned that there are significant disadvantages to a typical PES approach, several of which are as follows:

1. Successful PES programs typically focus narrowly on one or another ecosystem service, in part because designing payment programs even for one service can easily become quite complicated.
2. Markets can undervalue farmers' stewardship of natural capital and ignore value that cannot be easily quantified.
3. Determining a recommended price for a unit of ecosystem service can be difficult, which the Working Group found during the course of its process. These challenges are discussed in Chapter V.
4. PES programs can find it difficult to consider "whole farm" or more integrated, holistic approaches.

5. PES commodifies nature and could potentially introduce Vermont resources to international capital markets and their risks and vagaries.

Over the course of its meetings, the Working Group became aware that the language and concepts of "payment for ecosystem services" and "natural capital" are tied to the much larger developments related to the "financialization of nature" and the "privatization of the commons". During the period in which the Working Group has operated, "natural asset companies" have emerged as a new class of publicly traded assets on global financial markets. This new asset class was designed to create a new market whose assets "generate trillions of dollars in ecosystem services annually".[13] This development represents an alignment of banking and corporate interests around the potential to profit from putting a price on ecosystem functions. Several Working Group members have expressed serious concerns about how the Working Group's work could promote a dangerous trend toward the financialization of nature and the privatization of the commons, which would involve increased risks to farmers and deprivation of their agency.

In response to these concerns, the Working Group considered other ways to value stewardship beyond a strict buyer-seller relationship or a strictly transactional PES program. The Working Group coalesced around an approach that reduces the emphasis on a precise transactional valuation of ecosystem services and places more emphasis on recognizing producers for their good stewardship of their agricultural land while encouraging and supporting producers with lower stewardship levels with improving.

What are ecosystem services?

In the 2020 report to the Legislature, the Working Group shared a definition of ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life"[14] i.e. "the set of ecosystem functions that are useful to humans."[15] By adding other forms of capital and investment to alter human management of agricultural systems, people may amplify the benefits provided by ecosystems and may glean additional value from the ecosystem services. The perceived or estimated value may be monetized, but can also be measured in other terms, including satisfaction (e.g., recreational enjoyment), public health costs avoided, or other less visible benefits.

The Working Group notes that "ecosystem services" as a paradigm has several biases: 1) it is human-centric and assumes nature is at the service of humans; 2) it measures benefits only insofar as humans value them and ignores the value ecosystems provide to all of life; and 3) it reduces nature to a numeric monetary value to be captured and traded in economic markets. The Working Group values the many ecosystem functions that farmers steward, particularly those described hereinafter in this Report. At the same time, the Working Group is cautious of the term "service" and the connotations that it implies.

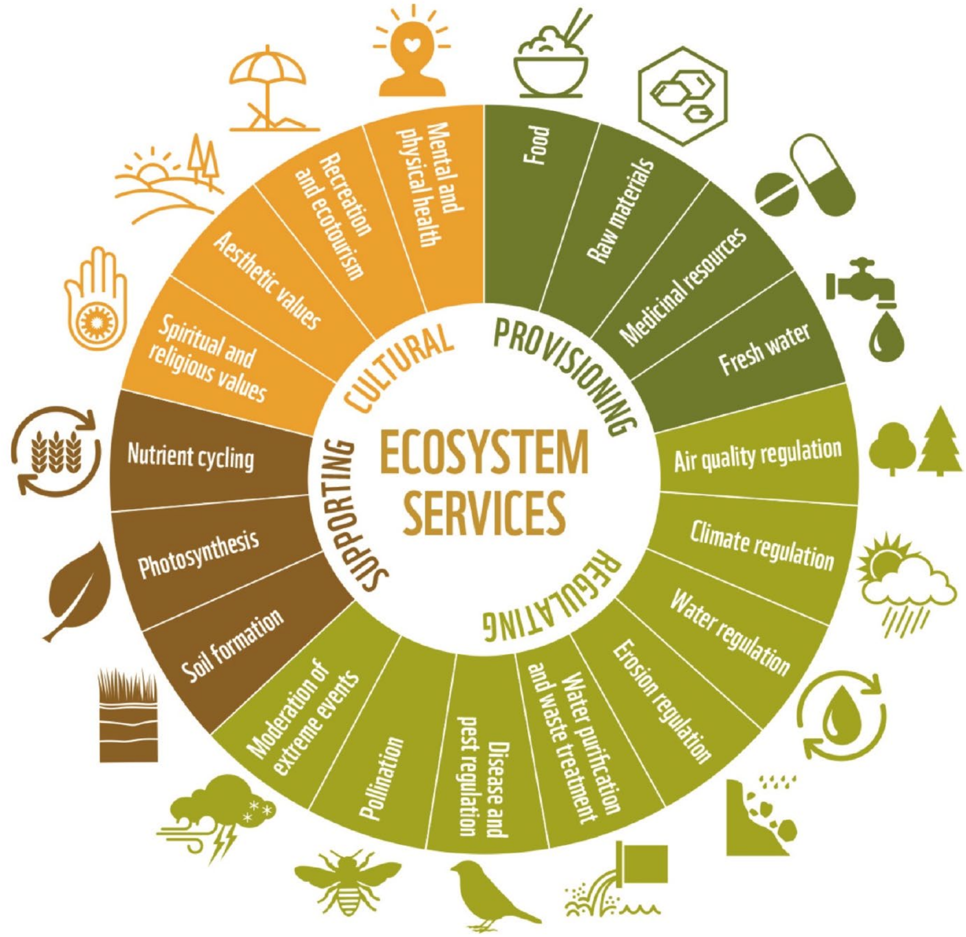
The diagram below[16] offers detailed examples of numerous ecosystem functions that are framed here as specific "services."

[13] Inter-American Development Bank, 'News Release - NYSE and Intrinsic Exchange Group Announce a New Asset Class to Power a Sustainable Future', 14 September 2021, https://www.iadb.org/en/news/nyse-and-intrinsic-exchange-group-announce-new-asset-class-power-sustainable-future.

[14] Gretchen C. Daily, 'Introduction: What Are Ecosystem Services?', in *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington, DC: Island Press, 1997), 4.

[15] Claire Kremen, 'Managing Ecosystem Services: What Do We Need to Know about Their Ecology?', *Ecology Letters* 8, no. 5 (May 2005): 468–79, https://doi.org/10.1111/j.1461-0248.2005.00751.x

[16] Taylor Rickets. Ecosystem Services Presentation to the PES Working Group. https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/PES/Ricketts_Act83_WG2.pdf (2019)



Perhaps the most recognized ecosystem function delivered by farms is the provisioning of food and fiber. It is worth noting that payments for even this most tangible function often do not capture the full range of costs that farmers bear to cultivate food and fiber.

Natural capital

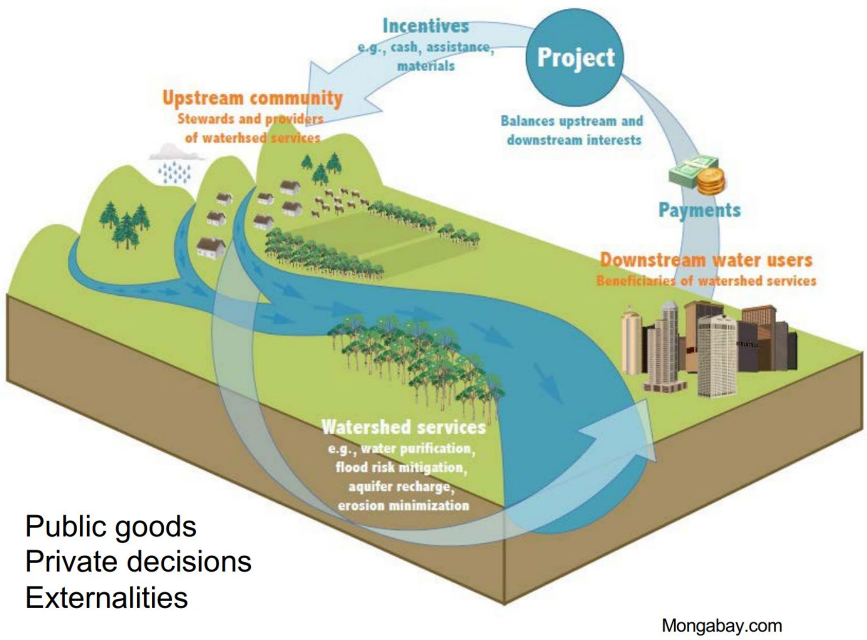
The Working Group also considered the concept of *natural capital,* though it also poses similar paradigmatic problems to those noted about "ecosystem services". Under this framework, nature provides (and humans can degrade) natural capital – naturally occurring resources such as healthy soils, functional landscapes such as wetlands, and perennial native vegetation – that sustain both human production and natural systems over generations. *Natural capital results in ecosystem services.*

The Working Group considered soil health as a foundational element on farms that provides "natural capital" for many ecosystem functions. This framework enabled the Working Group to move toward a more systems-based approach that can yield more interconnected environmental benefits than focusing solely on one or another function.

How does a payment for ecosystem services approach work?

The Working Group also outlined in its 2021 interim report that ecosystem services often provide public goods, but private decisions influence the quantity and quality of the provisioning of these ecosystem services. Those who steward the land are not always those who benefit. For example, water quality improvements from nutrient retention practices on farm fields help the entire watershed. Flood mitigation from improved infiltration of soils benefit downstream and downgradient land users. Carbon sequestration provides global benefits in the collective effort to mitigate climate change. Commodity markets often fail to account for such ecosystem functions. Therefore, they fail to compensate for the improvement to the natural capital from production of agricultural commodities. Likewise, they also fail to penalize when the production of agricultural goods degrades the land and attendant ecosystem services. Monetizing the benefits of ecosystem services and rewarding farmers through a payment for ecosystem services is one strategy to incentivize the stewardship of land to yield public benefits. However, there may also be dangers to this "financialization" of ecosystem functions, which are discussed under "Limitations of payment for ecosystem services". As the Working Group learned, there are alternative approaches to reward good stewardship of natural resources through other means.

A PES, as classically defined, involves a transaction where a well-defined service is 'bought' by at least one ecosystem service buyer from at least one ecosystem service provider, if and only if the provider secures the ecosystem service provision.[17] For instance, if a farmer changes their agricultural practices to reduce soil erosion, a payor might pay that farmer for the quantified reduction in tons of soil eroded below a regulatory standard. The diagram below[18] shows a general example from a watershed in which: 1) upstream communities provide services that benefit downstream users, and 2) how payments flow accordingly for those services.



The Working Group sought to learn about various PES programs in operation nationally and internationally to learn what works, what to avoid, and general best practices for designing a program. The Working Group's technical contractor surveyed ten PES programs to assist the Working Group's framing of a Vermont-focused PES program.[19] These included two Vermont-focused programs – the Vermont Pay for Performance Program and the Vermont Forest Carbon Project. The Working Group was

[17] Sven Wunder, 'Payment for Environmental Services: Some Nuts and Bolts', Occasional Paper No. 42 (Bogor: Center for International Forestry Research, 2005), https://www.cifor.org/publications/pdf_files/OccPapers/OP-42.pdf as offered in the Working Group's 2020 Report.
[18] Taylor Rickets. Ecosystem Services Presentation to the PES Working Group. https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/PES/Ricketts_Act83_WG2.pdf (2019)
[19] Christopher Bonasia, Lindsay Ruhl, and Nour El-Naboulsi, 'Review of PES Programs', Vermont Payment for Ecosystem Services Technical Research Report #6 (University of Vermont, February 2022).

also made aware of a regional assessment of over 1,300 ecosystem service programs and policies across the northeastern United States.[20]

Paying for performance vs. paying for practices

In understanding the best approach to program design, the Working Group grappled with the competing concepts of paying for *practices* and paying for *performance.* 'Pay for practice' programs identify a set of agricultural practices (such as reducing tillage, planting cover crops, and extending crop rotations) with documented conservation benefits. These programs compensate agricultural producers for implementing these practices, often on a per-acre basis. The advantage of practice-based payments is that they can be evidenced-based with research done nationally or regionally and that they are relatively easy to describe, implement, and monitor to ensure they were implemented to standards. An example of this principle in practice is the state's agronomic pay-for-practice programming, under which over 300,000 acres of conservation practices have been implemented in Vermont since 2016. While the agricultural sector has received only 26 percent of the state's investment in water quality programming, the sector has delivered 96 percent of all phosphorus reductions reported by the state since 2016, most of which is a result of the state's agronomic pay-for-practice programming.[21]

On the other hand, performance-based payment programs identify quantifiable conservation *outcomes* and associated metrics that can either be measured or monitored. Performance-based programs will then compensate agricultural producers for the units of the metrics conserved, for example, pounds per acre of nutrients retained or tons per acre of carbon sequestered. Performance-based programs focus on outcomes themselves rather relying on the assumption that practices will lead to those outcomes. They seek to pay farmers for these outcomes based on clear market or other societal valuations. In other words, performance-based programs have the advantage of focusing on "what" is produced and leaving the "how" up to the farmer. The disadvantages of performance-based programs are that they require monitoring which can be prohibitively expensive and time for the farmer to show measurable benefit which can delaying payment.

The tradeoff between performance and practice-based systems can be understood in terms of risk placement. Practice-based programs offer secure payments to agricultural producers who successfully implement practices and place the risk that the practice may not deliver the desired or complete outcomes on the *buyer*. In comparison, a performance-based program may place a high level of risk on the *producer* that their management strategy may fail to deliver the desired outcomes.[22]

The risk on farmers is highest in a strictly measurement-based performance approach. Under such an approach, farmers' payments would be dependent on measurable changes to indicators of interest. However, farmers may take actions that end up having no appreciable measurable benefit for a year-on-year basis and will thus not get paid. For instance, in a strictly performance-based program that relies on soil health as a proxy for providing various ecosystem functions, for some soil health indicators (such as soil carbon) it can take as many as five to seven years before changes can be detected.[23] Relying on strict pay-for-performance in improvements to soil health could therefore ultimately require that producers would have to wait several years before receiving payments. This performance-based approach that relies

[20] Alicia F. Coleman and Mario Reinaldo Machado, 'Ecosystem Services in Working Lands Practice and Policy in the U.S. Northeast: Successes, Challenges, and Opportunities for Producers and Extension' (Kansas City: Extension Foundation, 15 April 2022), https://online.flippingbook.com/view/749315583/2/.
[21] Vermont Agency of Administration et al., 'Vermont Clean Water Initiative 2021 Performance Report', 15 January 2022, https://dec.vermont.gov/sites/dec/files/wsm/erp/docs/Reports/2021CleanWaterInitiativePerformanceReport_FINAL_updated%201-20-2022.pdf.
[22] Bonasia, Ruhl, and El-Naboulsi, 'Review of PES Programs', 12–13.
[23] Alissa White et al., 'Field Scale Soil Health Scenarios', Vermont Payment for Ecosystem Services Technical Research Report #2 (University of Vermont, May 2022), 5.

solely on measurement could therefore place significant risk on the producer over a longer period than a practice-based program generally would. In other words, farmers would be deprived of 'certainty'.

Programs manage this risk tradeoff in various ways. For example, the Vermont Pay for Performance program (a performance-based program) offers a data entry payment to farmers and then a performance-based payment per pound of phosphorus reduced from a baseline. It also uses a "hybrid" model that seeks to quantify the outcomes of evidence-based practices through using basic farm-specific data (soil type, slope, weather, etc.) and modeling to arrive at calculated or derived ecosystem outcomes rather than by using farm-by-farm field-based measurement. This modelling-based performance approach requires significant inputs of data upfront but allows programs to forecast improvement in ecosystem services, which in turn allows compensation to the farmers to occur at an earlier timeframe.

The advantages of hybrid modeling-supported approaches include: 1) lower monitoring and measurement costs; 2) evidence-based practices with inclusion of some specific farm data; and 3) the ability, depending on the model, to assess multiple ecosystem services and anticipated benefits. The disadvantage is that these approaches do not measure actual outcomes and are constrained by the assumptions and limitations of modeling. Models can also be seen as "black boxes" to program participants as it may not be apparent how inputs translate into results.

The role of soil health

As outlined in the 2020 interim report, the Working Group focused on healthy soil as an essential part of Vermont's "natural capital" to invest in and rebuild. A focus on soil health provides a focal point for action and plausibly addresses several desired outcomes, including improved farm productivity. Healthy soil as described in 6 VSA § 4802(4) means soil that has a well-developed, porous structure ('spongy'), is chemically balanced, supports diverse microbial communities, and has abundant organic matter. Healthy soil is central to the sustainable, productive, and climate resilient cultivation of food and crops in Vermont and provides a host of additional environmental, economic, and social co-benefits. A framework that rewards farmers for rebuilding healthy soils could potentially improve many ecosystem services simultaneously and provide a framework for a viable, sustainable, and regenerative Vermont agricultural system.

The Working Group's technical contractors conducted a survey of 179 farmers in Vermont, the results of which reinforce this emphasis on soil health. The survey found that 99 percent of Vermont farmers believe improvements in soil health have benefits for the environment off their farm, 95 percent of Vermont farmers believe that they should take additional steps beyond required practices to protect soil health, and 90 percent of Vermont farmers believe they have a responsibility to be part of climate solutions.[24] These findings suggest that Vermont farmers have an innate understanding of their responsibility for soil health management and that the value of their management practices extends beyond their farms.

What ecosystem services did the Working Group focus on?

The Working Group, based on its legislative charge, deliberations, and research from its technical contractors, prioritized the following ecosystem services as the key services which could be feasibly linked as measurable outcomes to farmer improvements in soil health management:

1. Climate regulation, particularly carbon storage and sequestration
2. Climate resilience, that is, the ability of food production and the associated landscape to be resilient in the face of more intense heat and storm events brought about by climate change[25]

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[24] Alissa White, 'Results of the 2022 Vermont Farmer Conservation & Payment for Ecosystem Services Survey', Vermont Payment for Ecosystem Services Technical Research Report #3a (University of Vermont, June 2022), 6.

[25] 10 V.S.A. § 590(4) "Resilience" means the capacity of individuals, communities, and natural and built systems to withstand and recover from climatic events, trends, and disruptions.

3. Downstream flood risk mitigation
4. Soil conservation
5. Biodiversity

The Working Group recognizes that ecosystem services do not operate in isolation but are intrinsically linked with one another. Therefore, while it is useful to assess ecosystem services individually to understand their relationship to soil health, the Working Group took the approach of understanding the joint value of ecosystem services from agriculture and how ecosystem services are "stacked" within an area of land to produce multiple co-benefits.

The Working Group also explored where on the farm these services might be provisioned, including in the soil, in the field, at the edge of field, in the farm's forest, on the farmstead, and on the farm as a whole. For guiding an initial program, the Working Group concluded that the program should focus on outcomes in the soil (e.g., improved carbon sequestration), in the field (e.g., more diverse cover crops to support biodiversity), and at edge-of-field (e.g., increased stormwater retention) while considering outcomes in other parts of the farm.

Water quality has also been a topic of interest for the Working Group. The Working Group recognizes that Vermont farmers can make (and are already making) substantial contributions to water quality through farm practices across the farm that are not exclusive to soil health. The Working Group also learned that there is a positive directionality between the adoption of water quality conservation practices (such as cover crops, no-till, and management intensive grazing) and improvements in soil health. At the same time, *how* farmers implement those practices is key to assessing the attendant impacts to water quality. The technical contractor recommended that the Working Group rely on tools like the Vermont Phosphorus Index and USDA's Agricultural Policy/Environmental eXtender model to assess water quality outcomes.

IV. Definition of healthy soils, method for measuring soil health, and recommended tool

As mentioned earlier, 6 VSA § 4802(4) defines "healthy soil" as "soil that has a well-developed, porous structure, is chemically balanced, supports diverse microbial communities, and has abundant organic matter." Healthy soil is central to the sustainable, productive, and climate resilient growing of food and crops in Vermont and provides a host of additional environmental, economic, and societal co-benefits. As a related concept, the Working Group discussed the concept of the "soil sponge", which is defined as the structural and functional integrity of soils, which in turn is dependent on the biological integrity of the land, both above and below ground. The concept of the "soil sponge" helps illustrate that soil health has both structural and functional aspects and highlights the role of biodiversity for soil health and related ecosystem services. The Vermont Healthy Soils Coalition presented a webinar to the Working Group on the interrelated benefits of soil health and the soil sponge.

There is no single measure of soil health – many biological, physical, and chemical characteristics of soil that relate to ecological function can be measured as indicators of soil health. The Working Group identified a list of five measurable characteristics that could be used as indicators.

1. Organic matter (the portion of soil that consists of decomposed plant and animal tissue);
2. Aggregate stability (the ability of soil aggregates to resist disintegration when disruptive forces are applied);
3. Bulk density (a measure of soil mass per volume and an indicator of soil compaction);
4. Greenhouse gas (N_2O and CO_2) emissions; and

5. Soil biodiversity (the mix of living organisms in soil).[26]

The technical contractors studied the above indicators and found that four of the five metrics are feasibly measurable: organic matter, aggregate stability, bulk density, and soil biodiversity.[27] They found that the cost and time required to measure greenhouse gas flux from soil surface would be cost-prohibitive. Models for greenhouse gas flux exist (varying from weak to moderate accuracy), though they may not capture all management practices for Vermont. Measuring soil carbon is a feasible alternative and requires multi-year monitoring and collection of bulk density cores.

The Cornell Comprehensive Assessment of Soil Health (CASH) test is an existing test that assesses scores for several attributes against regional baselines and renders an overall score. The CASH test's attributes overlap with the Working Group's priority indicators to some degree and would allow for comparisons with data from across the region. However, the Working Group was concerned that the CASH test did not necessarily capture all indicators of interest to the group, and that the index associated with the CASH test may not be sufficiently calibrated to farming systems in Vermont.

The Working Group explored the possibility of a "Vermont soil health index," which would combine the various indicators of interest to the Working Group into a single score to represent soil health in Vermont. Creating such an index would need to follow a facilitated process to determine how heavily each indicator weighs in the overall score. Such a process would also require ample time, resources, and technical expertise.

Additionally, the technical contractors studied and illustrated how changes in management practices on Vermont farms can influence these five soil health indicators at the field scale.[28]

The technical contractors explored the feasibility of a modeling-based approach to monitoring soil health indicators based on such changes in management. Such an approach, if feasible, would reduce operational costs compared to field measurement (due to reduced costs for labor, shipping, sample-collection, and testing). While it was not currently financially feasible for the Working Group to measure greenhouse gas emissions from soil surface, models like USDA's COMET-FARM are able to estimate CO_2 and N_2O flux based on farm management practices. However, COMET-FARM does not assess the other four indicators of interest.

As a result of these limitations of existing models, the Working Group explored the potential for the development of a new model or the modification of existing models to estimate all five indicators. Such an approach would reduce the costs of direct measurement for a PES program. Nonetheless, there would still be the need to collect field data to develop models and provide inputs into the models to estimate additional soil health parameters.

Ultimately, the Working Group determined that modelling, combined with the use of indices, could more satisfactorily capture the full range of ecosystem services of interest to the group than most forms of direct measurement. However, the Working Group also desired to make sure that its recommended approach did not place an undue data management and reporting burden on farms and decided to leverage the work of an existing program that assesses and compensates for soil health stewardship.

The approach to leverage the Conservation Stewardship Program (CSP) explained further below was favored by the Working Group, because CSP evaluates soil health through multiple Resource Concern Categories across each land use required to be evaluated for agricultural CSP applications. In addition to national Resource Concern Category evaluations, NRCS-VT also includes its State Priority Resource Concerns (PRC) for evaluation in Pasture and Cropland Groups using the USDA Conservation

[26] Alissa White et al., 'Measuring Ecosystem Services from Soil Health', Vermont Payment for Ecosystem Services Technical Research Report #1 (University of Vermont, December 2021), 3–5.
[27] White et al., 'Measuring Ecosystem Services from Soil Health', 2.
[28] White et al., 'Field Scale Soil Health Scenarios'.

Assessment Ranking Tool (CART). PRCs that are evaluated through CSP for cropland and pastureland uses include: concentrated erosion, degraded plant condition, field sediment, nutrient and pathogen loss, soil quality limitations, terrestrial habitat, and wind and water erosion. CART's assessment of soil health extends beyond the physical, chemical, and biological metrics of a soil, and includes a more holistic evaluation of plant, soil, and attendant edge-of-field environmental conditions that result from current and planned farm management. The Working Group sees this as a very positive element of CSP.

V. Recommended price for a unit of soil health or other ecosystem service and challenges around determining a recommended price

The Working Group's approach to determining a price was focused on understanding two components of a recommended price: 1) the amount that economic models would be willing to pay for a unit of soil health based on the ecosystem services generated and 2) the amount that farmers would be willing to accept for providing ecosystem services through the management of their farms.

By examining these two payment rates on a per-acre basis, one could better understand the rate markets are willing to pay for quantified environmental outcomes and in principle determine a price that society could pay that would compensate farmers adequately for their provision of ecosystem services. The Working Group's technical contractors studied these questions, though it is important to note that the scope of research did not include a survey or assessment of the public's 'willingness to pay' to support farm viability and the achievement of enhanced ecosystem service delivery from farms in Vermont.

In order to better understand the cost – or value – of ecosystem services provided by agricultural land management changes, the technical contractors investigated preliminary valuation estimates for four ecosystem services generated by improvements in soil health – climate regulation (carbon storage), nutrient retention (phosphorus loading reduction), soil erosion control, and flood runoff mitigation.[29] (The technical contractors also investigated potential options for valuing soil biodiversity but found that none were feasible within the scope of their study.)

The technical contractors assessed benefits from two scenarios for soil health improvements, termed within the paper as ambitious ("best") improvements and "good" improvements. The "best" scenario is defined as a 50 percent increase in soil organic matter and 20 percent decrease in soil bulk density compared to the reference condition. The "good" scenario is defined as a 25 percent increase in soil organic matter and 10 percent decrease in soil bulk density.

According to the parameters assessed through this research, "best" improvements in soil health on Vermont farms could yield benefits worth an additional $34 per acre per year above baseline thresholds across the suite of four ecosystem services combined per year. Similarly, the technical team found that "good" improvements could yield benefits worth an additional $17 per acre per year above baseline thresholds per year. These values ($34 and $17 per acre per year) represent a payment and valuation strategy whereby the benefits would be paid annually, in perpetuity, for achieving and maintaining those soil conditions (50%/20% and 25%/10% improvements for soil organic matter/bulk density respectively). Members of the Working Group felt strongly that these numbers undervalue some ecosystem services due to assumptions and estimations made in the research, in addition to varying perspectives on the value of less quantifiable benefits of these ecosystem services. It is also worth stressing that while these are estimates of a value of these ecosystem services (improvements of soil organic matter and bulk density conditions in the soil) to Vermont, they are not estimates of what society would be willing to pay or would need to pay for these services to achieve these effects in other sectors.

The technical contractors also investigated the minimum payment levels that farmers would be willing to accept for provision of ecosystem services through their management of soil health. They surveyed 179

[29] Benjamin Dube et al., 'Valuation of Soil Health Ecosystem Services (Version 2)', Vermont Payment for Ecosystem Services Technical Research Report #5 (University of Vermont, July 2022).

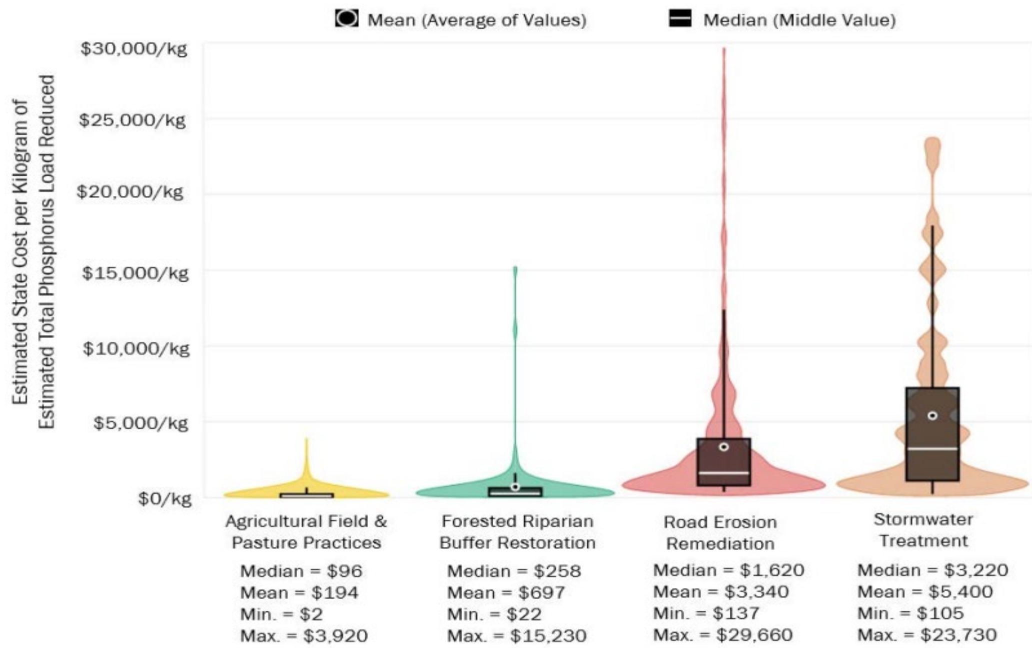
farmers in Vermont and found that the mean per acre compensation rate for meeting soil health threshold goals under a program was $206.[30] The technical contractors further investigated the payment rate by interviewing 35 Vermont farmers to explore their perspectives on compensation associated with a payment for ecosystem services and soil health program. That follow-up study found that mean minimum and preferred per-acre payment rates required by farmers for *maintaining* soil health were $40 and $186 respectively. Furthermore, the mean minimum and preferred per-acre payment rates required by farmers for *enhancing* soil health were $269 and $843 respectively.[31] Interestingly, there was broad variation in the average numbers both generally and by farm size. The technical contractors also mentioned anecdotally that producers found it difficult to come up with a concrete dollar figure in response to these questions.

Given these results, there is a clear difference between the economic valuations of ecosystem services from soil health and the payment levels that would be meaningful to producers for them to maintain or enhance soil health on their farms. Structuring a program around the economic valuations of the identified ecosystem services runs the risk of paying producers less than would be meaningful for them. Furthermore, it would raise concerns about whether producers would voluntarily enroll in such a program that pays them less than they would voluntarily accept.

Additionally, the technical contractors' assessments of farmers' willingness to accept payment rates (that is, the additional cost they bear to implement soil health management practices) and the value of ecosystem function improvement costs diverge from the actual costs of conservation practice implementation to meet environmental goals in Vermont as reported by the Vermont Clean Water Initiative 2021 Performance Report.[32]

The figure below taken from the Clean Water Initiative's 2021 Performance Report, illustrates investment per estimated kilogram of total phosphorus load reduced over the lifespan of each project type, based on clean water projects funded through State of Vermont agencies completed SFY 2016-2021 (excluding local and federal leveraged funds).[33] It is clear that the state receives, by far, the strongest "bang for the buck" in phosphorus reduction through agriculture-related clean water projects.

[30] White, 'Results of the 2022 Vermont Farmer Conservation & Payment for Ecosystem Services Survey', 31.
[31] Ellen Friedrich et al., 'Farmer Perspectives on Administrative Burdens & Potential Compensation Structures', Vermont Payment for Ecosystem Services Technical Research Report #3c (University of Vermont, August 2022), 8.
[32] Vermont Agency of Administration et al., 'Vermont Clean Water Initiative 2021 Performance Report'. https://dec.vermont.gov/sites/dec/files/wsm/erp/docs/Reports/2021CleanWaterInitiativePerformanceReport_FINAL_updated%201-20-2022.pdf
[33] The violin plots, pictured at left, combine a box plot (see black rectangles/lines) and a density plot (see colored shapes). A box plot shows the minimum, maximum, median, and average cost effectiveness values. A density plot shows the relative number of projects falling into each range of cost effectiveness. Wider sections of the colored shapes represent more projects than thinner sections.



The ecosystem service valuations from the technical contractor utilized figures from Vermont wastewater treatment facilities that calculated a phosphorus pollution cost of $58.82 per pound of phosphorus. However, actual median costs to the State of Vermont for reducing phosphorus have far exceeded $100 per pound for every sector but agriculture. For example, median prices for phosphorus abatement for stormwater treatment practices are over $3,000 more per kilogram than compared to agriculture. A reassessment of ecosystem service valuation for phosphorus abatement with actual costs to the State of Vermont would greatly increase the value of phosphorus, on an annual basis.

Furthermore, it should be noted that any payment levels for the pilot approach would have been determined based on the funding already appropriated by the Legislature in Act No. 185 of 2022, rather than a strictly market-based price.

The discrepancy in these results led the Working Group to reconsider structuring payments around a recommended price for a unit of soil health or ecosystem function. Instead, the Working Group's Vermont Farmer Ecosystem Stewardship Program pilot approach seeks to pay farmers for maintaining a stewardship *threshold* defined in their CSP contract. This approach allows for greater flexibility by outlining standards for farms to meet conservation goals while still paying farmers for meaningful contributions to conservation stewardship.

VI. Proposed vision, goals, and eligibility criteria

In June 2022, the Working Group came to agreement on its overall vision, goals, and eligibility requirements for program for the state of Vermont.

The vision was for a program that would promote climate resilience and mitigation, provide clean water, and improve the health of the broader ecosystem for all Vermonters, while also supporting the economic health of Vermonters engaged in agriculture.

The program goals were to:

- Compensate farmers for providing clearly defined ecosystem services or functions.

- Ensure that metrics and associated compensation are clearly and directly linked to the specific, quantifiable ecosystems services of carbon storage, nutrient, soil retention, stormwater retention, and ability to support biodiversity.
- Identify and pay for ecosystem services that could be provided by farms of diverse types and sizes, including those currently and historically underserved by payment programs.
- Be efficient with time and funding to ensure that a high return is provided to the farmer and society.
- Continually improve both research and the program to support agricultural innovation, adaptative management and development of new practices and tools.

In its Program Objectives, Elements, and Assumptions, the Working Group agreed that all farmers should be eligible to participate if they are in good standing with the Secretary of Agriculture, Food, and Markets (as defined under 6 VSA § 4802(3)). However, only those farmers who meet the standards and requirements set by the program will receive payments.

It should also be noted that NRCS Vermont applies a ranking system for CSP once applications reach the available funding levels. The adoption of this pilot program may drive CSP applications to a level where more competitive ranking may come into play based on funding available through NRCS. The Working Group supports maintaining a static Planning Completion Payment (PCP) along with the contract signing component of the Contract Incentive and Implementation Payment (CIP) for all farmers who complete the requisite conservation planning, and for those who go on to sign agricultural CSP contracts with NRCS. The remainder of the PIP will be prorated and distributed across all remaining grantees who successfully execute agricultural CSP contracts with NRCS. Similarly, the PCP and PIP will also be distributed to existing agricultural CSP farmers who wish to enroll in the pilot program. Details of this payment structure are outlined in Chapter VII.

VII. Recommended approach

What program options did the Working Group consider?

The Working Group explored ten potential approaches for a program. Five of these approaches came from the Agency of Agriculture, Food, and Markets (AAFM) based on the goals and priorities of the Working Group, three program proposals were led by three farmers (one of whom is a Working Group member), and two are existing programs developed previously by AAFM and the Vermont Agricultural Water Quality Partnership (VAWQP),

The proposals were as follows:

1. CSP+, proposed framework presented by Guy Choiniere, Jennifer Byrne, and Christopher Bonasia
2. VT PES Observed Metrics Approach, proposed framework presented by Scott Magnan
3. VT Healthy Soil Protection & Restoration Act, proposed framework presented by Stephen Leslie[34]
4. The Vermont Environmental Stewardship Program (VESP), existing framework managed by AAFM
5. The Vermont Pay for Performance Program (VPFP), existing framework managed by AAFM
6. Soil health testing via Cornell Comprehensive Assessment of Soil Health (CASH)
7. Soil carbon testing via soil bulk density tests
8. Soil carbon modeling via a process-based model
9. In-field observation with modeling assessment and payment
10. In-field observation with rubric-based scoring

[34] The technical services task 6b report (under Appendix Q) contains details for the three farmer-led proposals (1-3).

After receiving the $1 million appropriation from the Legislature in the FY 2022 budget, the Working Group began to focus on designing a pilot program that would utilize the appropriated funds as enumerated by the Legislature. The pilot program would be an initial program focused on demonstrating proof-of-concept and providing the ability to learn key operational lessons to advance a potential future program.

What program option did the Working Group decide upon?

Given varied drawbacks with each of the options noted above, the Working Group members decided to consider an alternative option, building from an idea first proposed by a group of small farmers to use the pilot appropriation to supplement payments to farmers in Vermont who enroll in the USDA Natural Resource Conservation Service (NRCS)'s Conservation Stewardship Program (CSP). This pilot program is named the Vermont Farmer Ecosystem Stewardship Program.

What is the NRCS Conservation Stewardship Program (CSP)?

CSP is the country's largest conservation program by acreage. The program aims to provide technical and financial assistance to farmers and ranchers to recognize their ongoing management efforts and incentivize additional conservation enhancements.[35] CSP also meets the definition of a threshold-based program, assessing, documenting, and requiring stewardship enhancements across cropland, pasture, associated agricultural land, and farmstead.[36]

As a result, the Working Group determined that CSP closely met Working Group's goals to compensate farms for the outcomes of their stewardship across the whole farm. The Working Group also appreciated that a pilot that leveraged CSP would in turn leverage and add value to existing financial and technical assistance in the state, which had emerged as a major goal of the Working Group over the course of deliberations.

To enroll in CSP, farmers work one-on-one with NRCS or contracted third-party planners to evaluate their farms' stewardship threshold eligibility using NRCS' Conservation Assessment Ranking Tool (CART).[37] CART is an index based model developed by USDA NRCS which evaluates each field individual based on farm management as well as field-specific properties (soil, slope weather) to evaluate 14 resource concern categories, including: soil quality limitations, field sediment, nutrient and pathogen loss, and terrestrial habitat considerations.

If their farms score sufficiently high, farmers can work with planners to select conservation activity enhancements in line with the farmers' objectives. Farmers that do not meet initial planning thresholds can instead enroll in NRCS' Environmental Quality Incentives Program (EQIP) – or other state financial or technical assistance programs – to address baseline resource concerns. After successful planning and (if necessary) ranking, a farmer is then eligible to sign a 5-year CSP contract with NRCS and receive annual payments for maintaining existing conservation levels and implementing conservation enhancements on their farms. The diagram below[38] outlines this process:

[35] 'Farmer's Guide to the Conservation Stewardship Program' (National Sustainable Agriculture Coalition, November 2020), 6, https://sustainableagriculture.net/wp-content/uploads/2020/11/CSP-2020-draft3-interactive-1-1.pdf.
[36] Threshold programs reward farmers who exceed a conservation standard.
[37] USDA NRCS. The Conservation Assessment Ranking Tool. *Initial Observations and Next Steps.* https://the-conservation-assessment-ranking-tool-nrcs.hub.arcgis.com . Accessed: January 13, 2023.
[38] Diagram from: National Sustainable Agriculture Coalition. *Farmers' Guide to the Conservation Stewardship Program*. https://sustainableagriculture.net/wp-content/uploads/2020/11/CSP-2020-draft3-interactive-1-1.pdf (2020).

Clients who enroll in CSP are eligible for four different kinds of payment from four different program elements:

1. Stewardship Threshold Payments for meeting Resource Concern Categories[39] for each land use assessed
2. Land use Payments
3. Enhancement Practice Payments
4. Base Payments [Optional]

With all four payments combined, annual payments can be as high as $40,000 per farm annually. Producers, regardless of acreage, who meet the standards and successfully enroll in CSP are guaranteed to receive a minimum annual payment of $1,500.

What is the Working Group's Vermont Farmer Ecosystem Stewardship Program in detail?

The Working Group's USDA-NRCS Conservation Stewardship Program with Vermont State Enhancement pilot approach would supplement CSP payments to new enrollees with flat-rate lump sum payments at specific points in the CSP planning and contract process:

1. A **Planning Completion Payment (PCP)** upon completion of conservation assessment and planning with a CSP planner;
2. An upfront **Contract Incentive and Implementation Payment (CIP)** upon signing of a 5-year agricultural CSP contract

[39] Resource concerns include but are not limited to: wind and water erosion (sheet and rill), concentrated erosion (ephemeral or classical gully, streambank and shoreline), soil quality limitations (organic matter, soil life, tilth, compaction, etc.), storage and handling of pollutants (nutrients, pesticides, heavy metals, petroleum, etc.), degraded plant condition (health and productivity, plant community structure), terrestrial habitat for wildlife and invertebrates (threatened species, pollinators, etc.), and aquatic habitat for fish and wildlife, including
water temperature.

3. An upfront **Practice Incentive Payment (PIP)** will also be awarded to those farmers signing the 5-year CSP contract to support implementation of enhancement practices needed to meet CSP standards.

In addition, producers who, at time of pilot program rollout, are already enrolled in an agricultural CSP contract will be eligible for a one-time supplemental payment that mirrors the PCP and CIP payments new enrollees will receive to support their continued implementation of their contracts.

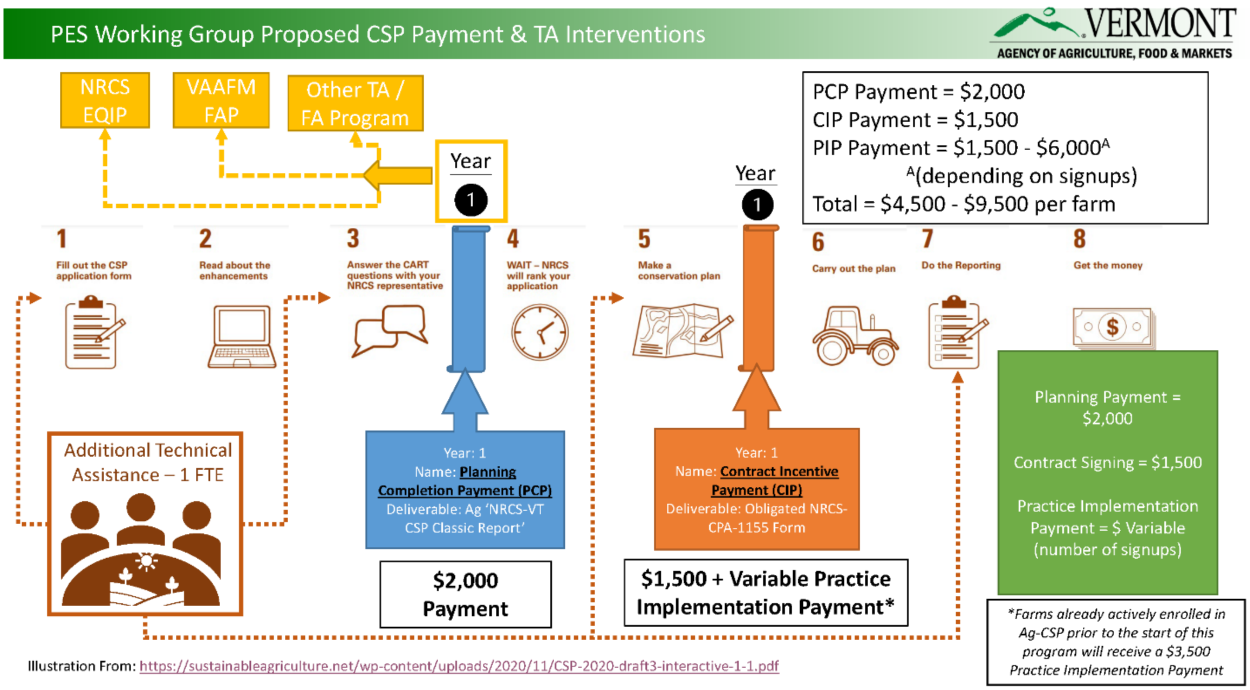


Figure 1 This diagram outlines the technical and financial assistance program interventions envisioned by the Working Group's PES Pilot

The payment interventions outlined in Figure 1 were identified by the Working Group as areas of existing bottleneck that have proven to be historic obstacles to farmers enrolling in the CSP program. While CSP can be beneficial in the out years, there is significant upfront planning and costs that a farmer much shoulder before seeing renumeration. The PES pilot program recommended by the Working Group seeks to strategically inject financial assistance payments to support the necessary planning and implementation necessary for farms to achieve CSP stewardship thresholds and successfully participate in five years of conservation practice implementation.

The Working Group's pilot approach would also devote a portion of the pilot funds toward one full-time equivalent of conservation technical assistance staff time to supplement existing NRCS and third-party planners with enrolling additional clients in CSP. This additional technical assistance is anticipated to be necessary due to the expected increase in CSP applications due to the Working Group's pilot program. This additional technical assistance will also assist with education and outreach and could also help create more demand for the CSP program, resulting in further applications.

There are several advantages to this approach from the Working Group's perspective.

1. The Vermont Farmer Ecosystem Stewardship Program leverages an existing program that focuses on incentivizing environmental stewardship and the provision of ecosystem services.
2. The higher state-supplemented base payment will incentive greater CSP participation and thus greater stewardship. The Working Group heard from several producers with farms of diverse

sizes and crop types who are currently enrolled in CSP that the program is valuable to them, but that the low base payment is a barrier to enrollment.

3. CSP allows farmers to pick from several conservation enhancements to address resource concerns, allowing farmers to decide the approach that would work best for them and their farm.
4. The state-supplemented upfront payment provides support to farmers to undertake the initial planning, which has been named as a barrier to higher participation in the program.
5. The upfront state payment on top of the annual payments from NRCS will provide farmers additional capital to implement their conservation enhancements.
6. The state payment enhancement would fund additional one-on-one support and technical assistance from planners for clients and potential clients. The Working Group heard that the current availability of technical assistance to support enrollment in CSP would benefit from being bolstered.
7. The flexibility of the pilot program (and CSP) is an asset because it provides an opportunity to expand the program and invest more deeply, focus on specific natural resource concerns in the future, and add other elements in future phases that are not currently included.

Ultimately, the Vermont Farmer Ecosystem Stewardship Program pilot should lead to: 1) higher enrollment in CSP; 2) greater farm viability given payments from both state and federal funds to farmers; 3) enhanced conservation practices and activities; and 4) enhancement of ecosystem functions, including but not limited to increased carbon storage, nutrient, soil, and stormwater retention, and the ability to support biodiversity.

VIII. Methods for incorporating the recommended approach into existing research and funding programs

The Working Group's pilot approach will build directly on the USDA-NRCS Conservation Stewardship Program (CSP) by providing funds to farmers and increase enrollment in the program. The pilot also builds on lessons learned from the Vermont Environmental Stewardship Program (VESP). VESP was a voluntary pilot program that encouraged agricultural producers to achieve high environmental standards through responsible land stewardship. Participants in VESP were eligible for additional technical and financial assistance to meet their stewardship goals and were socially recognized if achieved thresholds for environmental stewardship across their farm.

AAFM's Agricultural Clean Water Initiative Program (Ag-CWIP) education, outreach, and technical assistance funding program to support partners who work with farms to improve water quality across the state of Vermont through education and outreach, technical assistance, organizational capacity development, and conservation practice surveys. Ag-CWIP already supports several initiatives of interest related to the Working Group's goals, such as grant opportunities for farmers and other stakeholders to investigate metrics related to water quality and ecosystem functions. Ag-CWIP will continue to provide much-needed technical assistance to coordinate farmer enrollment in existing funding programs.

While the Working Group's pilot approach already represents a collaboration between USDA-NRCS and the State, there is the potential that the pilot could inform an application for USDA NRCS' Regional Conservation Partnership Program (RCPP) to formalize and add funds to that collaboration. RCPP provides funding for partnerships between NRCS and other entities that seek to develop solutions to natural resource challenges on agricultural land. The Working Group's Vermont Farmer Ecosystem Stewardship Program pilot approach could lead to a future RCPP application for a version of CSP tailored to the specific needs of Vermont farmers.

The Working Group also learned from several of its members and other stakeholders that navigating the range and variety of state and federal funding programs can be seen as a challenge for farmers who seek to leverage these opportunities. Although many funding programs exist, farmers are often unaware of the range of options available, which ones might be best suited to their needs, and how to apply for them. The

Working Group subsequently identified several potential actions to ameliorate this complexity under *Other Considerations* further below.

IX. Potential future benefits

The Working Group's pilot program approach will yield several benefits to farmers and the state more broadly. Firstly, the program will yield improvements in ecological health and function of Vermont's agricultural land. At the same time, it will incentivize and pay for improvements in soil health outcomes on Vermont farms. An additional benefit is that the pilot will yield improvements in water quality and data for tracking progress in the state's water quality efforts.

Secondly, the pilot will yield tangible benefits to Vermont farmers through direct funding to farmers – a key desire of farmers within the Working Group and beyond. In addition to funding, the pilot program will provide direct technical assistance to farmers from NRCS or third-party planners to support them in conservation planning and addressing resource concerns on their farms. Critically, farms of diverse sizes, types, and land tenure arrangements will be able to benefit from the program.

Thirdly, the program would set the state up to leverage increased incoming federal funding for USDA and NRCS under the federal Inflation Reduction Act of 2022, which includes increased appropriations for CSP and other programs like EQIP and RCPP.

The projected duration of the pilot program would be three years (2023-2025) with the potential for a longer-term program based on lessons learned during pilot implementation.

X. Estimate of the cost to the state

As of the drafting of this report, the Working Group anticipates that all $1,000,000 of the funding appropriated in Act 185 of 2022 [Sec. B.1100(a)(7)(A)] to the efforts of developing a program will be obligated by the close of State Fiscal Year 2025. A detailed budget of the pilot program can be found in Appendix G. At least65 percent of program funds are planned to be distributed to farmers for planning for and implementing conservation plans that will improve ecosystem service delivery of their farms through the CSP program. Twenty-five percent of program funds are planned to be used to support additional conservation technical assistance staff at qualified organizations that will support farmers to navigate the new CSP program. 6 percent of program funds are expected to be retained for administrative services, grant, and contract development by the program administrator. There currently is an anticipated shortfall in funding for administrative services for the program administrator.

As discussed within the Working Group, this pilot could represent the first 'phase' of a three-phase program development plan. As proposed, phase 1 would be the pilot proposal as outlined; phase 2 could be an increasing focus on particular resource concerns, potentially incorporating the pilot into a NRCS Regional Conservation Partnership Program (RCPP) application; and phase 3 could be geared toward even more targeted payments for specific performance outcomes.

If the pilot program is successful, the Working Group anticipates that future State of Vermont budget requests will be needed to sustain farmer participation in the CSP program and to access matching funding from USDA NRCS which will enable phases 2 and 3 of the pilot program to be supported through matching programming through the NRCS Regional Conservation Partnership Program and the federal Inflation Reduction Act of 2022. This vision of phased development and implementation will need to be informed by a process of continuous improvement and review of program goals and hurdles on an annual basis – at least.

The Working Group agreed that the pilot should have a preliminary 12-to-18-month review to address:

1. How the program worked, including number of number of plans completed, enrollees who joined, payments made, and enhancements undertaken.
2. What was learned from administering the program, from planning and base payments to ease of administration to who joined and why.
3. How farmers and technical assistance providers experienced the program
4. How much additional conservation the State gained through the CSP state-enhancement

XI. Proposed funding or source of funds

The funding for the pilot would come from the FY 2022 budget appropriation for the Working Group's pilot program, along with resources from USDA NRCS-Vermont.

Should the state pursue an RCPP grant in the future, the funding for that program would come from NRCS with matching monetary or in-kind contributions from the state. It may also be possible that future phases could leverage funds from USDA Rural Development, the US Environmental Protection Agency, and federal funding for environmental remediation, among other sources. These funding requirements and opportunities would become clearer as more is learned from implementation and operation of the pilot.

XII. Other considerations

Biodiversity

The Working Group identified biodiversity is a key ecosystem service provided by farms in Vermont. Microorganisms and fauna in soil participate in several ecosystem functions, including the formation of soil structure, carbon and nutrient cycling, decomposition of plant and animal matter.[40] For these reasons, biodiversity is generally regarded as a supporting ecosystem that regulates other ecosystem functions. As an ecosystem function, it provides benefits both locally (to the farm operation) and even more broadly by providing a foundation for other ecosystem functions and conserving genetic resources. The Working Group included soil biodiversity as a measurable indicator as part of overall soil health and biodiversity beyond soil as an ecosystem service. The technical contractors found that it would be feasible for a program to include soil biodiversity as a measurement. The CSP program currently includes terrestrial biodiversity in the form of assessment and ranking against terrestrial habitat considerations.

There are two general approaches for measuring soil biodiversity. One approach is to measure *functional* diversity, which "refers to those components of biodiversity that influence how an ecosystem operates or functions."[41] This approach seeks to capture the range of ecosystem functions carried out by the organisms present. The other approach is to measure the *amount* of biological diversity, which is often inferred as an indicator of diversity though not a direct measurement. Such approaches include measuring microbial biomass and respiration.

Soil biodiversity can also be measured at the *microbial* scale and/or by monitoring soil invertebrates (ranging from microscopic mites to earthworms to dung beetles) which play significant roles in the delivery of ecosystem services.

The technical contractors pointed out that, while there are methods of measuring soil biodiversity, it can be difficult to interpret results. Ideally, a locally relevant reference point should be selected from an optimal undisturbed or otherwise desired site.[42] Furthermore, the Food and Agriculture Organization of the United Nations recommends that soil biodiversity measurements should be "sensitive enough to reflect the influence of management and climate on long-term changes in soil quality but not be so

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[40] Ramesh Chandra, 'Soil Biodiversity and Community Composition for Ecosystem Services', in *Soil Science: Fundamentals to Recent Advances*, ed. Amitava Rakshit et al. (Singapore: Springer, 2021), 69, https://doi.org/10.1007/978-981-16-0917-6_5.
[41] David Tilman, 'Functional Diversity', in *Encyclopedia of Biodiversity (Second Edition)*, ed. Simon A Levin (Waltham: Academic Press, 2001), 587, https://doi.org/10.1016/B978-0-12-384719-5.00061-7.
[42] White et al., 'Measuring Ecosystem Services from Soil Health', 12.

sensitive as to be influenced by short-term weather patterns and robust enough not to give false alarms." Furthermore, "Such measurements must be robust and not subject to rapid (and unstable) rates of change, related to the basic methodological problem that soil biodiversity is highly dynamical."[43]

Working Group members explored methods for measuring soil and other on-farm biodiversity. One such method a draft "Biodiversity Matrix" submitted by one Working Group member that seeks to assess indicators of biodiversity across the farm and assign scores that can then be compiled into a final measurement (see Appendix I). The advantage of such an approach is that it could empower farmers to make specific changes in their farm management. However, a program would need to be able to conduct these qualitative assessments in a standardized way and any methodology would require peer-review to ensure that weightings are meaningful and relevant to conditions in Vermont.

Given the clear interest in biodiversity from the Working Group and the absence of consensus on metrics, the Working Group believes that resources should be committed toward researching approaches to measuring biodiversity and interpreting metrics, particularly around translating qualitative observations into robust quantitative metrics. This research would inform a broader program in the future.

Encouraging farmer participation

The Working Group sought to involve and be influenced by those with the most experience on the group – farmers. The Legislature established the Working Group at the behest of farmer watershed groups. The Working Group's membership includes four farmers (who have been active participants in the Working Group's process) and several other members who work directly with farmers across the state. The Working Group's technical contractors conducted an extensive farmer survey and follow-up interviews to obtain farmers' feedback on several program elements. Several members of the public (both farmers and service providers with direct relationships with farmers) brought additional farmer perspectives into the dialogue. At the same time, given the limitations of COVID, time, and the complexity of the issues involved, the Working Group recognizes that it did not engage the farming community as robustly as hoped through more outreach opportunities.

The continued involvement and support of farmer watershed groups and other farmers will be important for successful rollout and take-up of the pilot program. The watershed groups have also expressed interest in exploring innovative practices and approaches to measurement that could be incorporated in a future program. Grants from programs like the Agricultural Clean Water Investment Program could support projects to pilot metrics for ecosystem functions of interest to the Working Group.

Easing Navigation of Existing Programs

As noted above, the Working Group also learned from several of its members and other stakeholders that navigating the range and variety of state and federal funding programs can be a challenge for farmers who seek to leverage these opportunities. Other state-level initiatives have raised the concern about navigation – the Governor's Commission on the Future of Vermont Agriculture recommended in its 2021 Action Plan that the state "Establish a new full-time permitting, regulation, and funding 'navigator' position at VAAFM to assist a range of farm and food businesses streamline their experience of government programs and resources." The Working Group puts forward the following ideas for Legislative further consideration. It should be noted that the Working Group is also interested in and supportive of farmer-to-farmer peer networks where farmers leading on new approaches can share learning and support other farmers in doing so.

Farm Teams

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[43] Anton M. Breure, 'Soil Biodiversity: Measurements, Indicators, Threats and Soil Functions' (I International Conference on Soil and Compost Eco-biology, León, Spain, 2004), 90, https://www.fao.org/fileadmin/templates/soilbiodiversity/Downloadable_files/8.Breure.pdf.

The Working Group encourage greater use of farm teams in service delivery. Farm teams are designed for agricultural producers who work with multiple agricultural service providers (such as NRCS, UVM Extension, Conservation Districts, grazing specialists, business planners, seed and fertilizer consultants, bank loan representatives, and veterinarians). The mission of the farm team, comprised of some or all of the entities noted just above, is to streamline agricultural assistance and improve farm viability, while increasing adoption of on-farm conservation practices. Farm teams provide access to both technical and financial assistance. Meetings are scheduled at farmers' convenience and may be held on-farm or virtually via video conference call. As part of the pilot program, farm teams could be assembled for participating farms to help support implementation of the pilot and connect the farm to additional existing programs as well as serve as an opportunity to better understand programmatic gaps and challenges experienced by farmers and field-level technical service providers.

Programs Web Portal
The Working Group supports creation of a program web portal. An additional tool that would help farmers and their technical service providers navigate multiple programs would be an online portal that provides farmers with an initial assessment of the range of programs for which they may be eligible. Such an online portal could potentially consolidate or integrate multiple applications into one common application. Developing such a portal would likely require a multi-year effort.

XIII. Lessons Learned

The Working Group as it concluded its work identified some lessons learned, both in terms of substantive tradeoffs and challenges of creating a program and of the Working Group's process itself.

Firstly, as this report outlines, the Working Group spent substantial effort weighing the pros and cons of many choices concerning the design of a program. The contents of those deliberations are reflected in numerous meeting summaries, technical reports, and ultimately, the recommendations in this Report. Designing a program involves a difficult set of choices and trade-offs to create a functional program. These many choices arose from such questions as:

- Should all farms be eligible for a program, or should priority of funding be based on size of farms, specific resource concerns, and/or geographic location within the state?
- Should a program provide funding to those farmers who are already carrying out good conservation practices or only fund those farmers who need to do more?
- To what degree can and should additional resources go toward building on existing programs as opposed to creating a new and tailored program?
- To what degree should a program assess outcomes that can be directly measured, outcomes that can be modeled based on localized inputs, and/or practices known to be effective based on evidence-based trials?
- How should a program balance 1) the often-significant funding, time, and technical capacity requirements of measuring actual outcomes with 2) getting money into the hands of farmers for practices that are likely (but not guaranteed) to produce specific conservation value?
- What is the best way to integrate multiple ecosystem functions into a program, given that some are harder to measure than others (such as biodiversity, hyper-local flood mitigation, or greenhouse gas flux).
- How can a program integrate "expert-based", top-down approaches with more holistic, indigenous, and grassroots experiences on the ground?
- Should a program rely on trained technical staff to conduct robust assessments of farms or rely on simple self-assessment tools that can empower farmers in the assessment process?

The Working Group also identified several process-related challenges it encountered during its deliberations. The Working Group hopes that by sharing these challenges, future processes can learn from and consider them as stakeholders work to advance farm viability and sustainability in the state. These challenges include the following:

- The Legislature initially framed the solution as payment for ecosystem (PES), which relies on a quantifiable valuation approach that can limit the range and interaction of ecosystem functions under consideration. The PES framing also limited the extent to which the Working Group could take a whole farm or more holistic approach.
- Some Working Group members expressed difficulties with AAFM's role in convening versus leading the process, participating in deliberations versus receiving advice from the Working Group, and having deep technical and programmatic expertise yet also sometimes firm and fixed ways of doing business.
- There were three farmer watershed groups representing farmer interests and two additional farm representatives appointed to the Working Group, all of whom consistently attended meetings and consulted with their boards on key program updates. The technical contractor surveyed and interviewed farmers at certain points in the process, but some Working Group members wanted the process to more regularly solicit farmer feedback along the way. These members identified gaps in terms of educating a broader swath of farmers about the Working Group's findings and learning from farmers about their desires for a practical program. Given the complexity of the topic and the range of views, the Working Group needed extensive time among itself to contemplate and deliberate on complex choices, spending thousands of volunteer hours sorting through choices and options.
- Members expressed procedural concerns around matters including but not limited to the membership of the group, lack of clarity about the decision-making process and rules, the extent to which to focus on legislative charges, and the meaningful role for citizen and non-government Working Group members in the creation of government-organized and led conservation programs that is not perfunctory
- Several members were concerned about the process to identify, select, and contract with technical contractors. For instance, some Working Group members felt they did not have adequate notice about the technical contractors selected by AAFM during the summer of 2021, and that other technical contractors could have better responded to that RFP if AAFM had performed more direct outreach to the Working Group about this opportunity
- A stronger set of equity partners or more marginalized farmers and citizens as members would have brought more diverse points of view and ideas to the table with a greater attention to equity. There was an effort to involve an indigenous perspective in some of the meetings, but it was neither complete nor sustained.
- Some members felt that the Working Group did not have a clear enough roadmap of where it was ultimately heading, what topics to cover in what sequence to get to the destination, how to balance meaningfully between discussion and decision-making, and who gets to make what decision. There was a tension at times between being conversational and being decisive to ensure progress.
- The Working Group aspired to develop an approach that would result in a paradigm shift around Vermont's soils and agriculture and would transform Vermont's agricultural and ecological economy to be more regenerative, sustainable, and financially-sound. However, the practicalities of creating a fundable, implementable conservation program dampened these aspirations. The Vermont Farmers Ecosystem Stewardship Program will help make Vermont agriculture more regenerative, sustainable, and financially-sound, but will not result in full-scale transformation of the sector, as many members had hoped. That being said, all members of the WG expressed appreciation and confidence that the approach decided upon is based on evidence, informed by practical experience, tailored to Vermont, and will meaningful help support Vermont's farmers and ecosystems.

XIV. Appendices

Appendix A

Pursuant to Act No. 129 of 2020, Section 24, the Working Group included the following members:

1. the Secretary of Agriculture, Food and Markets or designee;
    a. *Deputy Secretary Alyson Eastman (Co-Chair)*

2. the Secretary of Natural Resources or designee;
    a. *Marli Rupe – Department of Environmental Conservation*

3. a representative of the Vermont Housing and Conservation Board;
    a. *Stacy Cibula (Co-Chair)*

4. a member of the former Dairy Water Collaborative;
    a. *Brian Kemp – Champlain Valley Farmer Coalition*

5. two persons representing farmer's watershed alliances in the State;
    a. *Paul Doton – Connecticut River Watershed Farmers Alliance*
    b. *Scott Magnan – Franklin Grand Isle Farmer's Watershed Alliance*

6. a representative of the Natural Resources Conservation Council;
    a. *Jill Arace – Vermont Association of Conservation Districts*
7. a representative of the Gund Institute for Environment of the University of Vermont;
    a. *Alissa White*

8. a representative of the University of Vermont (UVM) Extension;
    a. *Joshua Faulkner*

9. two members of the Agricultural Water Quality Partnership;
    a. *Matt Vaughan – Lake Champlain Basin Program*
    b. *Travis Thomason – NRCS Vermont*

10. a representative of small-scale, diversified farming;
    a. *Maddie Kempner – Northeast Organic Farming Association of Vermont*

11. a member of the Vermont Healthy Soils Coalition;
    a. *Cat Buxton or Didi Pershouse*
12. a person engaged in farming other than dairy farming;
    a. *Ed Pitcavage – Philo Ridge Farm*

13. a representative of an environmental organization with a statewide membership that has technical expertise or fundraising experience;
    a. *Heather Furman – The Nature Conservancy in Vermont*

14. an agricultural economist from a university or other relevant organization within the State;
    a. *David Conner – University of Vermont [now vacant]*

15. an ecosystem services specialist from UVM Extension;
    a. *Juan Alvez*

16. a soil scientist;
    a. *Meredith Albers – NRCS Vermont*

Appendix B

Meeting Date	Key Agenda topics
March 16, 2021	● Review of legislative charge and rules of the road ● Conservation Innovation Grant PES Effort ● National Conservation Innovation Grant with Vermont Land Trust and UVM Extension ● Agency of Agriculture, Food, and Markets updates ● Soil Health Network update
April 15, 2021	● Proposed work plan and creation of workstreams to advance tasks ● Workstreams kick-off in small groups
April 28, 2021	● Review of Working Group protocols ● Initiation of work plans in task groups
May 12, 2021	● Task group report outs and Working Group requests ● Small group discussions to advance task group work plans
May 26, 2021	● Questions to the full Working Group from task groups ● Small group discussions to advance task group work plans ● Report outs from task groups
June 9, 2021	● Questions to the full Working Group from task groups ● Small group discussions to advance task group work plans ● Report outs from task groups and outlines of next steps
June 23, 2021	● Programmatic questions for consideration ● Review of components of soil health to be measured and related ecosystem services ● Discussion of soil unit and pricing issues ● Planning for summer activities ● Next steps: structure and goals for fall Working Group activities
September 21, 2021	● Review of summer work and progress ● Vermont Climate Council and Future of Agriculture Commission: connecting and integrating with parallel efforts ● Work Plan for the remainder of 2021
October 5, 2021	● Scope of work for technical consultant support – oversight by and interaction with the Working Group ● Discussion on engaging farmers in the Working Group's development of options ● NSF grant update (University of Vermont)
October 19, 2021	● Discussion on CSP and CSP+ proposal ● Program structure development considerations ● Update and request for input from technical services team – 1) soil health draft matrix and scenarios and 2) program types and examples to explore
November 16, 2021	● Update from technical consultant on research tasks ● Soil health and its connections to other benefits, including biodiversity (VAAFM and Northeast Organic Farming Association of Vermont)
December 7, 2021	● Brief updates from technical consultant on research tasks ● Review of PES programs ● Program ideas (Scott Magnan & Stephen Leslie)

	• Ideas for measurement and quantification
December 21, 2021	• Farmer survey development • Valuation of ecosystem services from soil health • Review of PES programs • Measurement, quantification, and program design
January 4, 2022	• Discussion of valuation of ecosystem services from soil health • Detailed discussion on program design • Technical consultant activities for the first quarter of 2022 • Edge of field and whole farm approaches
January 18, 2022	• California Healthy Soils Program: lessons for program design • Discussion on measurement and assessment for program design • Technical consultant updates
February 1, 2022	• Review of approaches to valuation of ecosystem services from soil health • Program design updates • Debrief of California Healthy Soils Program presentation • Technical consultant updates
February 15, 2022	• Technical consultant updates • Brief review of existing "whole farm" programs • Presentation on a whole farm approach (Tony Fleming, Wild Farm Alliance) • Discussion on taking the ideas forward
March 15, 2022	• Valuation of reducing phosphorus loss and erosion and carbon storage • Small group discussions on "whole farm", "biodiversity", and "tiering" • Technical consultant updates • Update on PES funding proposals before the Legislature
April 5, 2022	• Net-zero farm operations with regards to greenhouse gas emissions • Farmer payment level survey & stakeholder engagement • Program design updates • Moving forward to detailed program design
April 19, 2022	• Farmer payment level survey & stakeholder engagement • Overview and discussion of draft program goals and objectives • Review of ground rules and decision-making
May 3, 2022	• Overview and discussion of draft program goals and objectives • Review of potential biodiversity metrics
May 17, 2022	• Update on farmer survey and interviews • Threshold and baseline payment options • Review and discussion of draft program vision, goals, and objectives
June 7, 2022	• Final review of program goals and objectives • Summer pilot development
September 20, 2022	• Stage-setting for fall 2022 • Review of draft pilot design options • Fall 2022 timeline and activities

October 4, 2022	• Debrief of pilot program options • October constituency outreach
November 1, 2022	• Overview of funding opportunities around technical assistance, navigation, and coordination • Overview of CSP with Vermont State Enhancement pilot program option • Questions, discussions, and refinements to the pilot option • Decision on a final pilot recommendation from the Working Group • Planning for the Working Group's 2023 report
November 29, 2022	• Review of draft report outline • Update on pilot development
December 13, 2022	• Update on pilot development • Review of draft report
January 3, 2022	• Update on pilot development • Review of draft report
January 10, 2022	• Update on pilot development • Review of draft report

Appendix C

SOIL CONSERVATION PRACTICE AND PAYMENT FOR ECOSYSTEM SERVICES WORKING GROUP REPORT

Prepared for the Vermont General Assembly in Accordance with

Act No. 83, Section 3 (2019)

Submitted to the

Senate Committee on Agriculture

House Committee on Agriculture and Forestry

By the

Vermont Agency of Agriculture, Food and Markets

January 15, 2020

Soil Conservation Practice and Payment for Ecosystem Services Working Group Report

January 15, 2020

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I. Executive Summary

Due to the initiative of three farmer-led watershed coalitions, the Vermont Legislature enacted Act 83 of 2019 charging the Secretary of Agriculture, Food and Markets to convene a Working Group to discuss Soil Conservation Practices and Payment for Ecosystem Services. This report fulfills the requirements of Act 83 Section 3 (2019) that the Working Group submit a report to the Senate Committee on Agriculture and the House Committee on Agriculture and Forestry. Between September 2019 and January 2020, the Working Group met in person five times and held six webinars with experts and practitioners who provided resources and perspectives to aid in the Working Group's thinking about payment for ecosystem service (PES) tools, metrics, and system design.

The Work Group focused not only on ecological services, but on the natural capital that provides these services, such as healthy soil ("a soil carbon sponge") that soaks up and filters water, functional landscapes, and biologically diverse ecosystems. This natural capital is the infrastructure needed for the provision of numerous goods and services that only healthy living systems can provide, such as flood protection, clean water, food security, and climate resilience and mitigation.

The Working Group developed a collective view of the future:

The Working Group envisions a system in which farmers are hired to use their ingenuity and know-how in caring for the land to rebuild Vermont's natural capital.

The Working Group concluded it should and can catalyze a paradigm shift in how farmers are acknowledged and empowered to perform their essential roles of environmental stewardship, as well as providing food and fiber. However, investment and capital, as well as technological, programmatic, and market developments that do not currently exist are essential to making this transformative change possible.

The Working Group learned that farmers, public, and the private sector across the country are exploring, often with substantial investment in the tens of millions of dollars, how to create payment for ecosystem services systems. It is important to note that Vermont is one of the locations at the forefront of how to conceptualize, create, and implement effective PES programs. Vermont's work is particularly new and innovative because it is (1) shifting thinking around externalized costs and (2) aiming to capture the complexity of ecosystem services and their benefits.

To help achieve its bold vision, the Working Group forwards eight key recommendations to the General Assembly for its consideration.

Recommendation #1: Charge and resource this Working Group over the next two years to explore and advance transformative investment in agriculture's role to rebuild the natural capital of Vermont.

Recommendation #2: Advance our understanding of soil health and the services it provides.

Recommendation #3: Review, evaluate, and integrate existing tools for PES monitoring and modeling and also identify new tools and their potential for use in Vermont.

Recommendation #4: Support the tailoring or advancement of new emerging tools or programs.

Recommendation #5: Advance the design and development of PES approach(es) that regrow or sustain our natural capital so that it provides at least three ecosystem services: water quality, flood resilience, and climate stability.

Recommendation #6: Refine and evolve the Vermont Environmental Stewardship Program (VESP) to allow continued joint learning and engagement with farmers around PES.

Recommendation #7: Maximize access and use of existing programs to ensure farmers have capital to continue to implement practices or actions that lead to increased ecosystem services.

Recommendation #8: Seek additional grant opportunities, where feasible, to advance the vision of the Working Group during its chartered lifetime.

The following sections establish a context and terms for these recommendations as well as describe each recommendation and its associated financial needs.

II. Charge of the Working Group and its Process

Act 83 of 2019, Section 3 outlined the legislative charge to the Secretary of Agriculture to convene the Working Group to discuss Soil Conservation Practice and Payment for Ecosystem Services. This charge called upon the Payment for Ecosystem Services Working Group (Working Group) to "recommend financial incentives designed to encourage farmers in Vermont to implement agricultural practices that exceed the requirements of 6 V.S.A. chapter 215 and that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters." This charge asked the Working Group to:

1. identify agricultural standards or practices that farmers can implement that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters;

2. recommend existing financial incentives available to farmers that could be modified or amended to incentivize implementation of the agricultural standards identified under subdivision (1) of this subsection or incentivize the reclamation or preservation of wetlands and floodplains;

3. propose new financial incentives, including a source of revenue, for implementation of the agricultural standards identified under subdivision (1) of this subsection if existing financial incentives are inadequate or if the goal of implementation of the agricultural standards would be better served by a new financial incentive; and

4. recommend legislative changes that may be required to implement any financial incentive recommended or proposed in the report.

This report fulfills the requirements of Act 83, Section 3 (2019) that the Working Group submit a report to the Senate Committee on Agriculture and the House Committee on Agriculture and Forestry, "including the findings and recommendations of the Soil Conservation Practice and Payment for

Ecosystem Services Working Group regarding financial incentives designed to encourage farmers in Vermont to implement agricultural practices that improve soil health, enhance crop resilience, and reduce agricultural runoff to waters."

Between September 2019 and January 2020, the Working Group met in person five times and held six webinars with experts who provided resources and perspectives to aid in the Working Group's thinking about PES tools, metrics, and system design. Summaries of the meetings and webinars are provided in appendices D and C, respectively. Over this short period, the Working Group began to address all of these charges, but the Working Group concludes that it needs additional time to develop and test the concept that has been at the center of the Working Group's discussion: to pay farmers for rebuilding natural capital in the soil and in a functional landscape to provide a host of ecosystem services.

III. Background on Payment for Ecosystem Services (PES)

What are ecosystem services?

Ecosystem services (ES) are "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life"[1] i.e. "the set of ecosystem functions that are useful to humans."[2] By adding other forms of capital and investment, people may amplify the benefits provided by ecosystems and may glean additional value from the ES. The value may be monetized, but can also be measured in other terms, including satisfaction (e.g. recreational enjoyment), public health costs avoided, or other benefits. In the context of farming in Vermont, key ecosystem services this group has identified to value are provision of clean water, flood mitigation, and carbon sequestration, in addition to the cultivation of food and fiber—the ecosystem services for which farmers are currently paid.

PES Framework and Terms

In this report we use several terms that we developed a working knowledge of in our dialogue. Graphic #1 below highlights these key terms.

Nature provides (and humans can degrade) *natural capital* – like healthy soils, functional landscapes such as wetlands, and perennial native vegetation – that sustain both human production and natural systems over generations. Natural capital results in various *ecosystem services*. A payment for ecosystem services approach, as this group envisions it, would compensate farmers for rebuilding the *natural capital* itself, which would produce measurable benefits like reduced nutrient runoff for improved water quality, improved flood resilience, improved public health, climate resilience, and economic stabilization and revitalization from reduced spending on externalities. This could be a more systems-based approach that can yield more interconnected ecosystem services than focusing solely on one or another ecosystem service.

A payment for natural capital and ecosystem services approach as this group envisions it would compensate farmers for producing measurable benefits like reduced nutrient runoff, improved water quality, reduced floods, or climate stability through the sequestration of carbon. This approach could allow farmers to innovate, adapt and combine practices and activities to produce the best outcomes according to the best means available on their land with their capacities. If a PES system can help farmers, agencies, programs, and markets focus on measurable outcomes and natural capital rather than

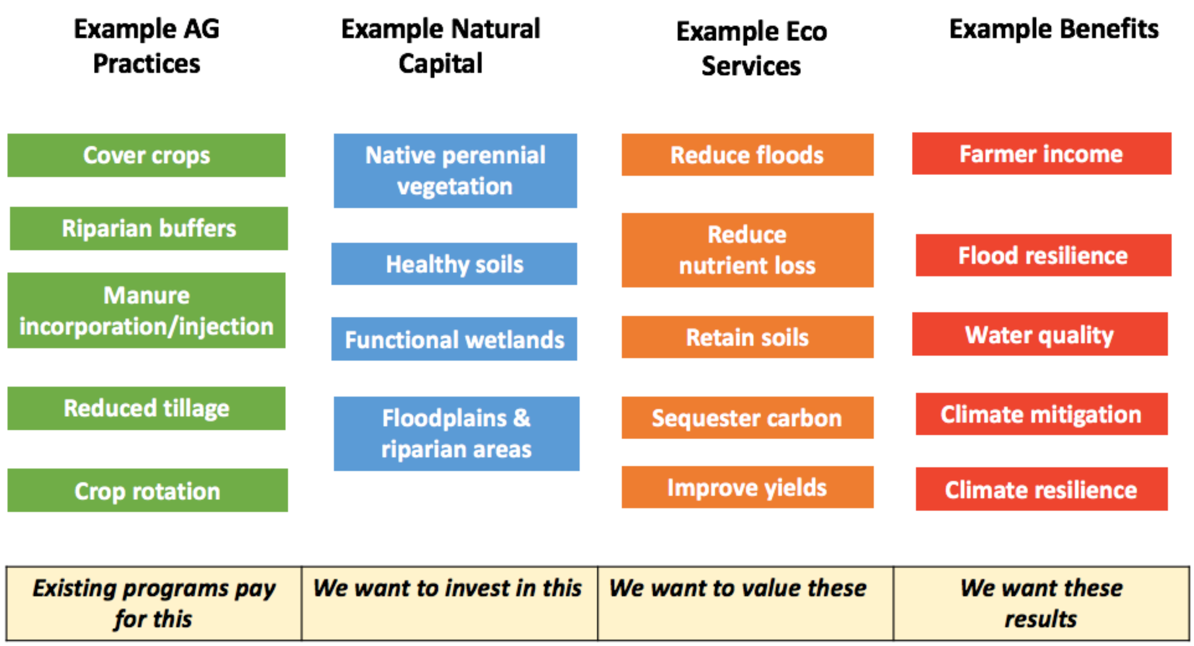
[1] Daily, G.C. (1997) Introduction What Are Ecosystem Services in Daily, G.C., Ed., Nature's Services Societal Dependence on Natural Ecosystems, Island Press, Washington DC, 1-10. - References - Scientific Research Publishing

[2] Kremen C (2005). 'Managing ecosystem services: what do we need to know about their ecology?'. Ecological Letters, 8, 468-479.

practices, we should be able to achieve greater benefits more efficiently, creatively, and with higher certainty.

Lastly, it should be noted that ecosystem services provide real, tangible *benefits* for people, including farmers and members of the communities in which farms are located. Some benefits accrue to society at large (climate mitigation), some to Vermonters (water quality), some to those downstream and nearby (flood resilience) and some to individuals (farmer income). Current agricultural best management practices also provide many of these benefits, however, the workgroup is recommending additional and more outcome-related opportunities.

Illustration 1: Description of Practices, Natural Capital, Eco Services and Benefits



How does a payment for ecosystem services system work?
ES often provide public goods, but they are influenced by private decisions. Those who supply the ES (or those whose land provides the service) are not always those who benefit. For example, water quality benefits from nutrient retention measures on farms help the entire watershed. Flood mitigation benefits from improved infiltration of soils benefit downstream and downgradient land users. Carbon sequestration has global benefits in the collective effort to mitigate climate change. The market often does not account for such benefits and so does not provide for nor reward many ecosystem services. Internalizing the benefits of ES through payment for ecosystem services (PES) is one strategy to ensure that public goods are stewarded by those whose land can provide them to address this problem of imperfect markets.

A formal definition of PES is a ***voluntary*** transaction where a ***well-defined*** ES (or a land use likely to secure that service) is 'bought' by at least one ES ***buyer*** from at least one ES ***provider,*** if and only if the ES provider secures ES provision.[3] For instance, a public agency might pay a farmer for the reduction in

[3] Wunder S. (2005). Payments for Environmental Services: Some Nuts and Bolts. Occasional Paper No. 42. CIFOR, Bogor.

soil erosion from their farm following a change in agricultural practices that the farmer considered, chose, and made.

PES systems have been created and operated in a range of contexts. Buyers range from municipal to national governments, international organizations, single corporate buyers, and others. Services bought include water quality, biodiversity, flood control, carbon sequestration, and others.

PES is an evolving policy and market tool. Some data are available on what types of PES frameworks have been created and what features have contributed to success in PES systems[4], though their potential applications and limitations are still being explored in a range of contexts. It is important to note that Vermont is on the forefront, along with others, of how to conceptualize, create, and implement effective PES programs. Farmers and agencies across the country are exploring, often with substantial investment in the tens of millions of dollars, how to create PES approaches that work.[5] This work is new and innovative.

IV. The Working Group's Vision

The Working Group envisions a system in which farmers are hired to use their ingenuity and know-how in caring for the land to rebuild Vermont's natural capital.

The group aims to catalyze a paradigm shift in how farmers are acknowledged and empowered to perform their essential roles of environmental stewardship as well as providing food and fiber. We envision a future where farmers are recognized as land stewards, where they are compensated from numerous and diverse income streams for their provision of a range of ecosystem services, and where the public invests in the rebuilding and restoration of our state's natural capital.

This paradigm shift involves transforming or expanding from:

- Farming land to stewarding it;
- Compensation for only crops and commodities to compensation for additional ecosystem services too;
- A focus on fields to one on landscapes;
- Compensation for practices (e.g., cover crops) to payment for performance (e.g., tons of soil retained) and investment in natural capital
- Modeling to monitoring; and,
- Assistance programs to realigned and internalized incentives, including through markets.

While each of these changes will occur at different times, some will be more complex than others, and some may never fully be achieved, together, these changes could transform how and what we in Vermont farm.

[4] Salzman, James, Genevieve Bennett, Nathaniel Carroll, Allie Goldstein, and Michael Jenkins. "The Global Status and Trends of Payments for Ecosystem Services." Nature Sustainability 1, no. 3 (March 2018): 136–44. https://doi.org/10.1038/s41893-018-0033-0.
[5] See the newly launched Ecosystem Services Market Consortium at https://ecosystemservicesmarket.org/

V. The Working Group's Key Findings

Context

Vermont agriculture is at a critical and urgent junction. Vermont farming confronts issues of low incomes, limited profitability, inadequate health and childcare, labor shortages, declining community support, and decreased acceptance and understanding of agriculture. The state risks losing its iconic and bucolic agricultural working landscape and the many cultural, economic and community attributes this landscape provides for Vermont. Addressing the financial viability of farming is urgent. Vermont has experienced a 32% loss in agricultural cropland over the past 30 years between 1987 and 2017.[6] In 2009, there were 1,091 dairies. In 2018, there were only 696.[7] In 2018 alone, 75 farms ceased operations.[8] Vermont has lost 20% of its shipping dairies in the last two years alone.[9] The loss of dairy farms is critical as they steward over 80% of the open land in Vermont and generate close to 70% of the farm gate receipts that undergird the foundation of all farming and agriculturally related businesses and activities.[10]

At the same time, environmental concerns around the quality of Vermont's waters also are front of mind. The Lake Champlain Basin has been assessed a phosphorus Total Maximum Daily Load (TMDL), there are nitrogen loading issues in the Connecticut River Valley and other lakes and water bodies across the state are under threat for a host of reasons. With the increased prevalence of cyanobacteria, or harmful algal blooms, Vermont residents and tourists have experienced the cumulative effects of pollution from the different land use sectors on Lake Champlain and other waterways in Vermont. These blooms affect the recreational value of Vermont's waters and result in loss of jobs and loss of tax revenue to the State. Research has demonstrated the potential loss in lakeshore property values and tourism revenue for Lake Champlain.[11]

With federal and state conservation programs, farmers have made meaningful strides in addressing nutrient contamination from farms into our lakes and rivers. In the Lake Champlain basin, agriculture has been the source of 41% of phosphorus loading.[12] While the Lake Champlain phosphorus TMDL called for agriculture to produce 67% of the required reductions in the basin, farmers have actually been responsible for 97-99% of reported phosphorus reductions between 2016 and 2019.[13] These reported reductions, which do not include many agricultural and other sector practices yet to be assigned a phosphorus reduction efficiency, reflect the cost-effectiveness of farming practices for nutrient reductions, the maturity of partner networks in promoting practice implementation and the willingness of farmers to take on their part of the TMDL. Even so, there is still much work to do and there is concern, despite all the hard work, that the goal of fishable and swimmable waters in Lake Champlain will not be met for some time.

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[6] USDA NASS Ag Census (2017). Table 1. Historical Highlights: 2017 and Earlier Census Years. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/Vermont/st50_1_0001_0001.pdf

[7] Vermont Agency of Agriculture, Food & Markets (2019). Vermont Dairy Data – December 2, 2019. Agency report.

[8] ibid

[9] ibid

[10] Vermont Agency of Agriculture, Food & Markets, Vermont Agency of Commerce & Community Development (2015). Milk Matters. https://vermontdairy.com/wp-content/uploads/2015/12/VTD_MilkMatters-Brochure_OUT-pages.pdf

[11] Voight B, Lees J and Erikson J (2015). An Assessment of the Economic Value of Clean Water in Lake Champlain. (Report No. 81). Grand Isle, VT: Lake Champlain Basin Program.

[12] Environmental Protection Agency (2016). Phosphorus TMDLs for Vermont Segments of Lake Champlain. https://ofmpub.epa.gov/waters10/attains_impaired_waters.show_tmdl_document?p_tmdl_doc_blobs_id=79000 at page 48.

[13] Vermont Agency of Administration, Vermont Agency of Natural Resources (2019). Vermont Clean Water Initiative 2019 Performance Report. https://legislature.vermont.gov/assets/Legislative-Reports/2020-01-14_CleanWaterPerformanceReport_SFY2019-FINAL.pdf

Current state and federal agricultural programs, including those focused on water quality, tend to pay for discrete practices, although they do not exclusively take this approach. A PES approach could take advantage of farmers' ingenuity and know-how to regenerate natural capital and to achieve outcomes across a functional landscape in a host of more tailored, innovative, and effective ways. Vermont can be a leader in rethinking both conservation and water quality programs, re-evaluating what farmers produce (not just crops, which are only one of many ecosystem services), and in creating additional income streams for farmers to invest in. For instance, would insurers be willing to invest in a landscape that is far less likely to have flood losses? Could town, state or federal funding for flood damage to roads be redirected towards creating a working landscape that soaks up rain? What entities might pay for approaches that sequester carbon?

However, this opportunity will take investment and capital as well as technological, programmatic and market developments that do not currently exist to make transformative change possible. The Working Group aims for these efforts to expand and enhance existing tools to measure, pay for, and strengthen ecosystem services to lay the groundwork for the transformational change that the group acknowledges is needed and ultimately seeks.

PES Principles

In exploring various PES approaches, the group also identified several guiding questions and criteria to be addressed. Some of these are assertions and some are questions that may require further investigation and research. These include:

- Paying farmers for producing services that go above and beyond Required Agricultural Practices (RAPs). Eligible participants should meet Required Agricultural Practices (RAPs).
- Investing in agriculture to evolve and transform behavior is a cost-effective place for society to invest in a range of environmental benefits.
- Identifying a baseline from which to measure performance, that includes recognizing good work already done by some farmers and including those who may not have had the opportunity to join past programs to participate, is important.
- Ensuring all farms, regardless of size, geography or product, have the opportunity to participate, while recognizing that small farms may not have the staff, technical resources, or financial capital to be as robust in their response.
- Utilizing Vermont- and farm-specific data to the greatest extent possible while ensuring data gathering does not overwhelm in both cost and time the payments to farmers for action.
- Determining if the intent is for a series of payments over time that diminish as performance advances, upfront capital assistance to achieve long-term sizable gains, or on-going annual payments in perpetuity to obtain the desired services, or some combination thereof.
- Setting prices and payments needed to both effect measurable and desirable change at the watershed or state-wide scale and provide meaningful additional income streams to or investments in farms.
- Seeking out new markets and additional dollars while drawing on and utilizing as effectively as possible current state and federal agricultural conservation programs as well as other public investments.
- Ensuring the administrator of the program is highly knowledgeable, trusted, flexible, innovative, and can deliver outcomes at reasonable costs.

Soil Health

The Work Group chose to focus primarily but not solely on healthy soil as an essential part of the state's natural capital to invest in and rebuild. A focus on soil health provides a focal point for action and plausibly addresses a number of desired ecosystem services, including improved farm productivity.

Healthy soil – spongy, organically rich, biologically diverse, and chemically balanced -- is central to the fertile and sustainable production of agricultural crops and provides a host of other benefits. A PES system that rewards farmers for rebuilding healthy soils could potentially improve many ecosystem services that the working group is interested in supporting in Vermont agriculture. Healthy soil could provide ecosystem services by:

- protecting and improving Vermont's water quality by retaining nutrients and minimizing soil erosion;
- improving infiltration of water, thus providing a valuable natural means to mitigate flooding;
- sequestering carbon, a much-needed action to mitigate climate change; and
- growing food and fiber more environmentally and economically sustainably.

We, as well as many others across the U.S., have more to learn about the nuanced, measurable, and multiple benefits that healthy soils can provide. More research is needed to establish the full host of soil health ecosystem services and to decide on metrics that more clearly define the correlation between soil health and some of these services. However, initial investigation demonstrates important connections.

Priority Research Questions
Through this preliminary work, the Working Group has identified a series of research questions that need to be addressed before the group makes final recommendations regarding the design and implementation of a PES approach. Among these are:

1. What ecosystem services or types of natural capital will be paid for? Does soil health or the building of natural capital provide these services in measurable ways?

2. How will these services and natural capital be measured? How will the efficiencies of modeling (based on robust models with locally relevant and accurate data sets) be balanced with the precision of farm-specific monitoring to measure actual performance? What existing, modified, or emerging new technologies can be utilized to truly measure performance and outcomes?

3. What are the cost-savings that can be expected and realized by improving ecosystem services? What are the existing externalized costs that Vermonters are already funding and how can these funds be redirected from effects to causes?

4. What private and/or public funding sources will be tapped to make these payments?

5. Who will be eligible to be compensated for providing these services? What payment scheme will best balance fairness (i.e. compensating for gains already made for farmers ahead of the curve as well as to those making improvements now) with efficiency (i.e. compensating for the largest improvements and greatest gains)?

6. How can this PES approach developed by this effort initiate a pathway towards broader market-based systems for compensating farmers for providing ecosystem services beyond state and federal programs only? What early steps does this approach need to take to work toward that goal? Who can best administer this or these PES approaches?

VI. Key Recommendations

The Vermont PES and Soil Health Working Group offers these recommendations to the Legislature:

Recommendation #1:
What*: Charge and resource this Working Group over the next two years to explore and advance transformative investment in agriculture's role to rebuild the natural capital of Vermont.*
To Whom*: The Vermont Legislature*
This Recommendation's Funding Request*: $90,000*

The Vermont Legislature formed the Soil Conservation Practice and Payment for Ecosystem Service Working Group, catalyzed by three farmer-led watershed groups proposing to work together to advance a PES approach. The WG has been powerful in bringing together related conversations and diverse actors around the state regarding soil health, ecosystem services, and the role of farmers in conservation. Our group, comprised of farmers, state agencies, federal agencies, academics, and advocates, has worked constructively to explore these issues and to quickly educate its members and one another about a range of issues related to soil health and ecosystem services. Our group has arrived at an ambitious, bold vision for the future of farming in Vermont. But our work has only just begun. In the time allotted, with five intensive meetings in a few short months, plus numerous webinars[14] and presentations, we were able to develop a general framework. This framework needs time, discussion, data, technical development, further research, and continued collaboration to build a clear, effective, empirically driven approach. This framework should also take advantage of programs being researched and developed nationally so as to benefit from current processes. We ask the Legislature to charge the Working Group to continue work over the next two years to help realize its bold vision.

While the Working Group's financial request noted below is significant, it should be noted that similar national efforts are receiving funds in the tens of millions of dollars to pursue PES in other states and regions. Furthermore, many of the costs of not paying for ecosystem services are already embedded elsewhere in the state's overall fiscal heath – post-flooding recovery costs downstream, declining farm income due to poor soil health, the future costs of mitigating climate change, losses in tourism dollars and public health costs of algal blooms in our lakes, and losses on farm due to drought and flooding.

These two years will allow us to undertake, support, and track several parallel work streams described below in further recommendations. These work streams can result in a focused, funded, technically justified, implementable PES approach of which the state can be proud. This approach would articulate the ecosystem services or natural capital to prioritize, a measurement system for soil health and other factors, a justifiable price for a unit of soil health or other capital or services sought, details on farmer/farm eligibility, and a forecast of impact, length of effort, sources of funds, and costs.

Specific Actions

1. The Vermont Legislature charges and funds the Working Group to continue for two years until December 31, 2021.

2. The Vermont Legislature adds membership categories to the Working Group in addition to the current membership as well as encourages alternates from the same or similar member organizations to provide consistent participation
   a. A representative(s) from agricultural use not currently represented on the group
   b. An environmental Non-Governmental Organization (NGO) with a state and national presence that can provide technical assistance and potential fundraising assistance
   c. An agricultural economist, preferably from an in-state institution or organization (to directly help shape valuation and financial questions)

[14] *see Appendix C that summarizes these webinars*

   d. One or more ecosystem services and UVM Extension specialists from Vermont able to translate programs and research to on-the-ground work, preferably from a state or federal agency or service provider
   e. A soil scientist to support the group in understanding and advancing soil health as a key area of focus

3. The Vermont Legislature provides up to $500,000 to support the group in advancing its work to create an effective, Vermont-tailored, implementable approach (*see Appendix A for more detailed budget*).

4. The Vermont Legislature provides, as part of that $500,000 request, monies for travel and participation stipends for non-paid WG members ($15,000) and the facilitation and outreach support needed to help the diverse WG be successful ($75,000)

5. Rename the Working Group from *Soil Conservation Practice and Payment for Ecosystem Services* to *Payment for Ecosystem Services and Soil Health* in order to emphasize the importance of soil health as natural capital and to move our focus from conservation practices to conservation performance.

Recommendation #2:
What*: Advance our understanding of soil health and the services it provides.*
To Whom*: State and Federal agencies and their grantees and technical providers*
This Recommendation's Funding Request*: $30,000*

The Working Group concluded that healthy soils are an essential natural capital that must be invested in for Vermont's future. Soil health has chemical, physical, and biological properties. Through complex interactions among these elements, healthy soil can be like a sponge, soaking up water in times of inundation and retaining more moisture in times of drought all the while producing crops and forage. We do need to learn more about the correlation between soil health and many of its possible ecosystem services. There are a number of existing research efforts that the Working Group can learn from, engage with, and potentially influence to advance the work of understanding soil health as a key component of natural capital. We need to learn more about soil capital, how it should be measured, by what metrics or tools, and the more precise stream of ecosystem services that arise from it. There are a limited number of specific research efforts the WG would want to support and initiate to better inform and ground their work, its conclusions and the actions necessary to make progress. These research efforts will be explored and refined in the coming months.

The Working Group can provide a forum where research teams can report their finding and learnings, where the group can influence and shape research design, to the extent possible, to advance shared goals. The Working Group might also engage with and consider appropriate roles on this topic with the Vermont Agricultural Water Quality Partnership (VAWQP). Questions range from the extent and quantity of ecosystem services that healthy soils can measurably provide, to which regenerative strategies lead to the best outcomes in water quality, soil health, carbon sequestration, and other factors, to what various types of monitoring can tell us about intended versus actual outcomes.

Specific Actions

1. The WG review, discuss, and agree to a specific definition of healthy soils.

2. The WG connect with other public and private innovative efforts around the country regarding defining, measuring, and rebuilding soil health in order to better understand the state of evidence linking soil health and the many ecosystem services we desire.

3. The WG support a technical synthesis of what is known and not known about soil health and various ecosystem services from nutrient retention to flood prevention, including the appropriate and best tools for modeling and monitoring soil health

4. For existing AAFM, NRCS, DEC, and UVM Extension research efforts like CEAP, incorporate into existing edge-of-field and other on-going studies as possible:
    a. measurements of soil health, most likely using the Comprehensive Assessment of Soil Health (CASH) tool, or key components of that tool supplemented with other metrics;
    b. gathering and analysis of data from edge-of-field research to identify more clearly the correlations among elements of soil health as measured by CASH and ecosystem services such as water quality, nutrient retention, flood storage, carbon sequestration;
    c. conservation approaches that involve regenerative agriculture concepts and decision-making strategies.

Recommendation #3:
<u>What</u>*: Review, evaluate, and integrate existing tools for PES monitoring and modeling and identify new tools and their potential for use in Vermont*
<u>To Whom</u>*: State agencies and institutions, Federal agencies, and private evaluators*
<u>This Recommendation's Funding Request</u>*: $30,000*

The Working Group has learned that there are a variety of tools from modeling to monitoring that have been or could be developed to help advance ecosystem service approaches. In no particular order, these include the Farm Phosphorus Reduction Planner (Farm-PREP), the NRCS Resource Stewardship Evaluation Tool (RSET), the Agricultural Policy Environmental Extender (APEX), the Comprehensive Assessment of Soil Health (CASH), and proprietary and emerging approaches developed or in development by private companies. However, we do not yet fully understand which of these tools are best fit for which purpose, which can harness actual or real-time Vermont-specific data, at what cost, and how these might be integrated into an overall approach.

Specific Actions

1. The WG will determine the specific ecosystem services and/or natural capital they want to focus on, which will inform which tools are used.

2. The WG recommends supporting two key reviews of existing and emerging tools and techniques.

    a. Review the strengths and weaknesses of monitoring and modeling tools used by various state and federal agencies regarding ecosystem services, the degree to which they utilized Vermont or field-specific data, their cost, how they might be integrated into a program or approach, and where further tool development or testing is needed. The Vermont Agricultural Water Quality Partnership (VAWQP), an interagency, state-wide partnership, as well as others could have a key role in this effort.

    b. Through an independent contractor or entity identify, describe, and provide an initial evaluation of new and emerging technologies and programs for measuring and monitoring outcomes and ecosystem services, particularly those seeking to gather real-time data, utilization of newer technologies be that satellite data, drone data, LIDAR, or other means, and that might put real time data quickly and clearly into the hands of farmers. This review should analyze where on the technological development spectrum each technology rests, how much investment would be needed to advance to a workable scale, and which tools might best meet the needs of Vermont. This should also include identifying existing private or private-public PES programs occurring at the regional or national scale and identify their tools and potential applicability to Vermont.

Recommendation #4:
What*: Support the tailoring of or advancement of new emerging tools or programs.*
To Whom*: Eligible and capable providers from the private or public sector*
This Recommendation's Funding Request*: $250,000*

Following what the WG learns in Recommendation #2 and #3, the WG believes that it will then have an opportunity to invest Vermont resources in key, select technologies to advance a powerful PES approach in Vermont that increasingly draws on real-time data and monitoring to pay farmers for producing clear, measurable outputs. Thus, the WG is recommending a significant investment in advancing core tools to make PES in Vermont effective.

Specific Actions

1. Based on the reviews completed in earlier recommendations, further refine and hone an approach to PES in Vermont that can achieve as many of the PES Principles, as outlined in the beginning of this Report, as possible.

2. Based on the reviews completed in earlier recommendations, through an RFP or RFI, the WG would solicit responses from capable and innovative entities (private or public) to advance key tools to allow PES program in Vermont to operate.

Recommendation #5:
What*: Advance the design and development of PES approach(es) that regrow or sustain our natural capital so that it provides at least three ecosystem services: water quality, flood resilience, and climate stability.*
To Whom*: The Working Group with Member Leads*
This Recommendation's Funding Request*: $0 since this development covered under a current NRCS grant*

The Working Group explored a host of desired ecosystem services, from pollination to flood prevention to nutrient retention to climate mitigation and resilience. The Working Group homed in, though not exclusively, on three in particular to start: 1) reducing flooding; 2) reducing nutrient loss to improve water quality; 3) increasing climate stability by sequestering carbon. The WG has initially prioritized these services because it is interested in establishing the relationship between each of them and soil health, and because the WG contends and hopes that they may each engage distinct and complementary stakeholders, approaches, and revenue streams. The WG recommends further research regarding each ecosystem service on these questions of possible sources of payments, the best scale and system design for the approach to be implemented, and the valuation of services that will result in the outcomes desired, in addition to how and whether these services could be combined or stacked. These three ecosystem service streams are closely related and overlapping. They are listed separately for clarity, though a desired outcome is an approach that can integrate these three plus others. This is a tremendous amount of work that is only now getting underway and hence the need for more time and resources for the WG to be successful.

Clean Water: Numerous state and federal programs and regulations, including the Vermont Required Agricultural Practices (RAPs), seek to require and incentivize farmers to reduce nutrient loss from their fields and farms. Most efforts to date have focused on a set of practices such as nutrient management, cover cropping, crop rotation, manure injection, and reduced tillage to achieve these goals. This approach would involve a demonstration project to design a PES program for decreasing or eliminating nutrient loss to accelerate and advance what some farms are already doing. The intent is to combine modeling and monitoring tools, needed incentives, and the appropriate technical assistance to create an additive approach to existing programs, that if successful, might even subsume or replace existing programs.

Flood Resilience: The Otter Creek Floodplain study in Middlebury[15] demonstrated that flood prevention through a variety of means, including the conservation of floodplains and the restoration of wetlands, could lead to significant avoided costs during a major storm like *Irene*. The Working Group wants to explore an approach involving upstream farms to benefit downstream owners and users on a local scale. For instance, by rebuilding spongy, absorbent, healthy soils in crop land and pastureland, creating retention basins, riparian buffers, and restoring wetlands, a farm may be able to provide significant avoided costs for downstream owners and private and public users. This approach would seek to understand how to build a local market for such services, how municipal and other funds might flow to farmers to provide this flood reduction service, how to value the service to result in action by the farmer and benefit to others as compared to repairing and rebuilding after a storm, and what actions might lead to the greatest results.

Climate Stability. Creating healthy soils and other activities on farms can provide an increasingly valuable function in sequestering carbon for the mitigation of climate change while also providing resilience in the face of climate threats, such as increases in flooding. There are emerging private markets that pay for carbon credits, including for sequestration of carbon. Regional, national and international efforts are underway to identify how to store carbon in the soil, what practices best retain carbon, how to measure the change in soil carbon, and how such sequestration activities can be paid for, at what price, and by whom. The Agency of Agriculture, Food & Markets is ready and willing to engage with expertise from elsewhere to help identify how Vermont and its farmers can reap the benefits of this growing market.

Specific Actions

1. Because an existing Conservation Innovation Grant let by USDA is already in place to undertake this work, we recommend the WG engage with the resources of the CIG along with the lead agencies on water quality (DEC and VAAFM), with the technical assistance of NRCS and UVM Extension, to advance this work together. *The WG is not asking for a specific line item budget for this task since is covered under existing NRCS funds.* This effort will:

    a. Focus on improving water quality at the watershed or state-wide scale through a performance-based PES approach rather than payments for practices.
    b. Explore flood resilience at the local scale as an ecosystem service of flood resilience
    c. Explore how to pay for sequestering carbon for climate change mitigation through emerging national or international markets.
    d. Determine if each of these should be approached separately, through a market or payment, or bundled together into a package of services to arrive at one payment for multiple results

[15] Watson, Keri B., Taylor Ricketts, Gillian Galford, Stephen Polasky, and Jarlath O'Niel-Dunne. "Quantifying Flood Mitigation Services: The Economic Value of Otter Creek Wetlands and Floodplains to Middlebury, VT." Ecological Economics 130 (October 1, 2016): 16–24. https://doi.org/10.1016/j.ecolecon.2016.05.015.

Recommendation #6:
What*: Refine and evolve the Vermont Environmental Stewardship Program (VESP) to allow continued joint learning and engagement with farmers*
To Whom*: VAAFM with the Working Group*
This Recommendation's Funding Request*: $50,000*

The Vermont Environmental Stewardship Program (VESP) has already enrolled several farmers in a pilot program, utilized a set of existing tools that use farm data inputs for modeling, and undertaken Vermont-specific monitoring. Thus, while the Working Group explores and details the many questions and areas of opportunity for a future PES approach, VESP should be expanded and oriented to provide an avenue for farmers to engage with the PES design process, providing their first-hand experience and know-how to inform design and value-based decisions about PES in Vermont, while benefitting from access to the evaluation tools VESP has and technical assistance to navigate other tools and assistance from related agencies. Participating farmers should be paid a stipend for their participation.

Specific Actions

1. Expand the Vermont Environmental Stewardship Program (VESP) as a means to educate, engage, and prepare farmers for a future PES approach.

Recommendation #7:
What*. Maximize access and use of existing programs to ensure farmers have capital to continue to implement practices or actions that lead to increase ecosystem services.*
To Whom*: NRCS, VAAFM, VACD, and others*
This Recommendation's Funding Request*: $0 since this would be accomplished through existing programs already funded within federal and state programs*

Agencies, watershed groups, and others should continue to engage farmers and inform them of the existing program opportunities for more PES-like approaches such as the Regional Conservation Partnership Program (RCPP), Environmental Quality Incentives Program's (EQIP) new flexibility, and the Conservation Stewardship Program (CSP), to name a few.

Specific Actions

1. Continue to connect farmers to programs that have PES-type features and that allow them to prepare for and reap benefits from emerging pathways for compensation for ecosystem service provision

Recommendation #8
What*: Seek additional grant opportunities, where feasible, to advance the vision of the Working Group during its chartered lifetime.*
To Whom*: The Working Group*
This Recommendation's Funding Request*: $0 since additional monies would be sought under this recommendation.*

The Working Group also recommends seeking out, where appropriate and possible, federal and private grants to advance key issues or areas. The Working Group does not intend to be a fundraising nor grant writing enterprise. That being said, such grants might help support technology and tool development, program design, and/or on-the-ground demonstration programs. Such grant programs include but are not limited to the USDA Regional Conservation Partnership Program (RCPP) and the Conservation

Innovation Grants (CIG). While none of these grant opportunities are guaranteed, time spent in grant development, if done in an efficient and targeted way, can leverage additional resources beyond the state's to advance the efforts of the Working Group.

Specific Actions

1. To supplement existing WG activities supported by legislative funding and seek out, where appropriate, eligible and useful, additional sources of funding for learning and implementation.

VII. Conclusion

The Legislature, by creating the Working Group in 2019, has meaningfully brought together diverse conversations, stakeholders, and expertise, to scope and frame the work ahead. But the work is in its early stages. The work of creating a viable, powerful, extensive payment for ecosystem services approach for Vermont is just beginning. Thus, the Working Group asks for the Legislature's sanction and support to continue to hone and bring to fruition the work we have started.

VIII. Appendices

A. Estimated Budget
B. Work Group Members
C. Working Group Summary of Webinars
D. Working Group Meeting Summaries

Appendix A: Estimated 18-month Working Group Budget 2020-2021

Rec #	Line Item	Value	Details
1	Travel and Honorarium for non-paid WG members	$ 15,000	10 meetings to up to 10 members for travel reimbursement and meeting stipend
1	Facilitation, Coordination, and Farmer and Public Outreach and Engagement	$ 75,000	
2	Soil Health and Ecosystem Services Evidence Based Review	$ 30,000	
3	Comparison and Review of existing state, federal, & university modeling and monitoring tools	n/a	Completed by WG members as part of their on-going work in other areas
3	Comparison and review of emerging tools, real-time monitoring, and PES programs	$ 30,000	An independent finding and comparison of promising new tools that might be used in, developed in, or tailored to Vermont
4	Research Pool for advancing the needed tools to create an evidence-based, innovative multi-ecosystem services approach for VT	$ 250,000	Based on the WG work, the research reviews noted above, the WG will prepare Request for Proposals for specific tool modification or development
2 to 5	Support for economic valuing of natural capital, various ecosystem services, current externalities, and identifying potential markets	$ 50,000	To provide on-going economic support for multiple tasks around valuing services and capital and exploring markets
6	Expansion of VESP program with farmer participation stipends for benchmarking and educating	$ 50,000	To increase participation and engagement in the VESP program
	TOTAL	$ 500,000	
	**Assumes 18-month budget, starting July 2020 through January 2022*		

Appendix B: Working Group Members

1. Alyson Eastman, Chair, Vermont Agency of Agriculture, Food, and Markets (VAAFM)
2. Nancy Everhart, Vice Chair, Vermont Housing and Conservation Board (VHCB)
3. Jill Arace, Vermont Association of Conservation Districts (VACD)
4. Cat Buxton and Didi Pershouse, Vermont Healthy Soils Coalition (VHSC)
5. Paul Doton, Connecticut River Watershed Farmers Alliance (CRWFA)
6. Vicky Drew, Natural Resources Conservation Service (NRCS)
7. Eric Howe, Lake Champlain Basin Program (LCBP)
8. Brian Kemp, Champlain Valley Farmers Coalition (CVFC)
9. Maddie Kempner, Northeast Organic Farming Association of Vermont (NOFA-VT)
10. Taylor Ricketts, University of Vermont Gund Institute for the Environment
11. Chuck Ross, University of Vermont Extension (UVM Extension)
12. Marli Rupe, Vermont Department of Environmental Conservation (DEC)
13. Tyler Webb, Franklin and Grand Isle Farmers Watershed Alliance (FWA)

Appendix C: Working Group Webinar Summaries[16]

10/11/2019: Soil Health
Cat Buxton and Didi Pershouse, members of the PES Working Group sharing a seat for the Vermont Healthy Soils Coalition, started off the webinar series with a presentation on the importance of healthy soil. In this webinar, Cat emphasized that improving soil health contributes to a wide variety of ecosystem services such as flood mitigation, water purification, greenhouse gas reduction, and local temperature regulation. Didi then outlined the potential for developing a bipartisan narrative focused around farmers creating a "soil sponge." This term refers to the fact that healthy soil has a strong matrix of biologically formed pores that enable the soil to better absorb and retain water and nutrients. Both presenters suggested that a PES system could pay for soil health based on avoided costs. For example, if the reduction in the forecasted costs of flooding damage from better land management could be calculated, farmers could be compensated accordingly.

10/23/2019: PES Program Design
Jon Winsten is an agricultural economist and independent consultant and is working with NRCS through CIG in the first stages of designing a pay-for-performance system in Vermont. He has also worked with the NGO Winrock on PES systems nationally and internationally since 2001, including a pilot study in Missisquoi River Basin ten years ago. His webinar emphasized that PES systems should be simple, cost-efficient and motivating to farmers. Jon advocated for a system that models the effects of various practices, allows farmers to choose which of those practices to implement, and then pays farmers for their "performance" based on the modeled results of those practices. He argued that such a system reduces risk on the farmer and is most motivating and cost-effective. This system was the foundation of the pilot program started in Vermont in the late 2000s. In his presentation, Jon further explored the tradeoff between scale and cost of measuring Ecosystem Services performance and recommended that in-stream measurements at the scale of small watersheds would be a good compromise.

10/28/2019: Comprehensive Assessment of Soil Health
Heather Darby, an agronomy and soil science specialist at UVM Extension, presented this webinar on the merits and limitations of the Comprehensive Assessment of Soil Health (CASH). Heather was involved in the creation of CASH, which she feels is one of the longest-standing, most comprehensive, most user-friendly tests for soil health available. She informed the PES Working Group that although she feels that CASH is an excellent tool for informing management decisions on farms, it would have its limitations as the foundation of a PES program. Heather doesn't believe there is enough evidence to correlate soil health metrics and ecosystem services outcomes. However, she suggested that an in-depth pilot study could build off past VT soil test results and take CASH measurements alongside other measurements, such as runoff and erosion rates, to calibrate models of ecosystem services. Heather further advised that any PES system based on CASH should be built on RAP compliance for payment, since CASH metrics don't inherently capture the implementation of practices required by that rule. Heather also commented that CASH is less expensive than most possible PES measurement systems, which she appreciates since she harbors a concern that the money PES systems spend on measurement and administration would cut too much into the potential payments to the farmer.

11/1/2019: Learning from Global PES Systems
Jim Salzman, professor of Environmental Protection and Law at UCSD, is an expert on global PES systems and a co-author of a peer-reviewed paper titled "The Global Status and Trends of Payment for Ecosystem Services" in the journal Nature. In this webinar he shared some takeaways from his research and this article, which identified over 550 active PES systems around the world. Jim informed the

[16] Webinars will be available for viewing at: https://agriculture.vermont.gov/pes

Working Group that most successful PES systems are publicly funded and those that aren't are privately funded by a single large corporate stakeholder. Almost all pay for practice. These trends are because those types of systems are simpler and simpler systems are much more likely to be successful. Jim also counselled that the Working Group pay attention to the political and social implications of the design of a PES system and advised the group to be intentional in their choices. He advocated that the Working Group "reverse engineer" a PES system and start by defining their goals for such a system, followed by the funding source and the restrictions that would provide, and moving towards defining the actual mechanism at the end of the process.

11/8/2019: Farmer-Led Measurement and Synthesis
Abe Collins is a Vermont-based grazing consultant and the co-founder of LandStream, a measurement technology and consultancy company. He presented this webinar on his vision of a comprehensive landscape-scale sensing system that would provide a platform for farmers to measure the ecosystem services of their farming practices across a variety of metrics in the landscape. He advocated strongly that farmers should lead the development of a PES system since they are the key stakeholders and are uniquely able to grow natural capital. Abe declared that current models and measurement for ES performance are inadequate to inform payment and advocated for a more synthesized, landscape-scale approach. He sees the need for a pilot project that performs in-depth, comprehensive measurements on at least 6 pilot farms, compares these results to remote sensing data and farmer observations, and builds a synthesized model for landscape function that could be used for PES going forward.

12/3/2019: Ecosystem Services Marketplace
Chris Kopman oversees the PES efforts at Newtrient, a company which has made a proposed protocol for PES. In this protocol, on an annual basis program administrators would model the effects and costs of field-specific practice outcomes, farmers bid on the funding they want to implement those practices, the program administrators review applications based on Return on Investment in $/lb, selected farmers implement, and then a third party verifies implementation before payment. Chris explained that modelling performance would enable the most money to be paid to farmers and that 3rd party verification of implementation would allow the program to certify reductions and issue payment. Chris advocates for modeling with the Farm-PREP tool, which is farm/field specific, calibrated to VT, and runs off NRCS-Apex. He also advocates for a pilot program but stipulates that it should focus on an outcome for which there is both demand and modelling capability. He explained that nutrient runoff fits those categories, while soil health and carbon sequestration are as-yet inadequately modelled. Chris further pointed out that although private markets offer long-term promise and some companies have stated interest in private PES, their stated goals tend to be closer to 2030 or 2050, which might be too long.

Appendix D: Working Group Meeting Summaries

Vermont Soil Health and Payment for Ecosystem Services Working Group

Waterbury, Vermont

September 30, 2019 Meeting Summary

Next steps

- The Co-chairs and CBI will schedule future meetings based on member availability
- Members will respond to a survey to help glean feedback on options before next meeting
- The Co-chairs and CBI will schedule webinars as soon as possible and make recordings available for those who cannot watch live.
- CBI will revise the ground rules/charter document per feedback from the Working Group
- AAFM will post meeting materials to https://agriculture.vermont.gov/pes

Introductions and setting goals for the process

Working Group Co-Chair Deputy Secretary Alyson Eastman welcomed the group and reviewed the charge of the Working Group, as articulated in Act 83 of 2019 of the Vermont General Assembly. She explained the intention to develop a program to recognize farmers stewarding Vermont's landscape and helping achieve the goals of improved water and environmental quality in the state. She emphasized that agriculture can and should play a role in reaching these goals, and that the loss of farms and farmland is concerning for the state. Co-Chair Nancy Everhart also welcomed the group and expressed the hope that the Working Group would, over the course of its five-month process, be able to determine a framework for next steps for a payment for ecosystem services (PES) system and recommend one or more pilot programs.

The Co-Chairs introduced the facilitator, Pat Field of the Consensus Building Institute, and explained that his role was to strengthen the process and remain neutral to help the group incorporate multiple stakeholder perspectives to collectively guide the outcomes.

Member introductions

Working Group members introduced themselves and the organizations or constituencies they represent. They shared hopes for outcomes of the process. Key goals Working Group members articulated included:

- Instituting an approach to land stewardship that encompasses the whole state.
- Catalyzing a paradigm shift that incents farmers to steward land rather than forcing them to exploit natural resources. Rewarding farmers for the range of environmental and social public goods they provide in addition to the private goods they produce.
- Increasing the viability and sustainability of farming in the state.
- Including broad problem-solving on the structure and functioning of the landscape in a PES program.
- Investigating innovative ideas with opportunities for increased rewards to address several elements of the land and soil health, not only more narrowly defined chemical/nutrient issues.
- Integrating the efforts of agriculture with that of other sectors working to improve water quality and environmental health.

- Balancing the efficiency and equity of a PES program. Recognizing farmers' efforts to improve while also acknowledging those who have instituted practices to improve ecological health.
- Avoiding a one-size-fits-all approach and respecting farmers' knowledge and ability to innovate to solve problems.

Scope and key questions

Working Group members offered the following key questions to address in the process to develop a PES program:

- What is the definition of soil health?
- Would a market function internally to Vermont, or interact nationally and internationally?
- What is the appropriate scale or unit for the program to work with to measure performance and benefits?
- Where will money come from for payments?
- What metrics will be used to calculate efficacy? Will metrics be based on practices or performance (i.e. services being provided.)
- How would the program interact with existing regulations?
- What has made other PES programs successful or not?
- How to ensure equity among farmers starting at different baselines?
- Can the system be adjusted over time to encompass more goals?
- Can this program be tied to other costs and sources of funding? E.g. highway departments, property insurers, municipal DPWs, etc.
- How to ensure some do not take undue advantage of the system and avoid unintended consequences?

Working Group members suggested that success at the conclusion of the five-month process would include:

- A pilot program and resolution of key questions to educate legislators.
- A process that adequately accounted for the voices of stakeholders not in the room, particularly the diverse range of small farmers.
- At minimum, framing policy questions legislators will need to decide to advance a PES system so they can make good decisions.
- Reaching consensus on technologies to measure and quantify services.
- The outcomes of the Working Group are effectively communicated to a range of audiences, including the legislature.

Working Group operating procedures and work planning

The group reviewed and suggested minor revisions to the operating procedures, which the Co-Chairs and facilitator agreed to make.

Working Group members will review technical and substantive material via several webinar presentations over the course of the process whenever possible, in order to maximize the time during meetings for group deliberation.

Review of Vermont's Agricultural Water Quality Regulatory Framework and Programs

Ryan Patch, AAFM Water Quality Division, provided an overview of existing agricultural and water quality regulations with which a new PES program would interact[1]. He explained that current regulations provide a definition of healthy soil: "Healthy soil" means soil that has a well-developed, porous structure, is chemically balanced, supports diverse microbial communities, and has abundant organic matter [6 V.S.A. § 4802(3)]. The regulations also establish standards for nutrient management on farms, including: recommended practices for improving and maintaining soil quality and healthy soils in order to increase the capacity of soil to retain water, improve flood resiliency, reduce sedimentation, reduce reliance on fertilizers and pesticides, and prevent agricultural stormwater runoff [6 V.S.A. § 4810a(4)(B)]. He also traced the evolution of water quality and agricultural regulations that led to the formation of this Working Group.

2016 amendments to required agricultural practices (RAPs) increased the responsibility of the agricultural sector to reduce nutrient loading to meet the total maximum daily load (TMDL) requirements. For example, agricultural contributions of phosphorous (P) are 41% of the total in the Lake Champlain Basin, but because agriculture can cost-effectively reduce P, the sector is responsible for 67% of reductions in the TMDL reduction requirements equation. The baseline outlined in the RAPs will meet many required standards, but farmers can do more and take some pressure off of other sectors to help meet water quality goals.

The state is aiming to reach TMDL goals as quickly as possible. The revision of the RAPs contributes towards that goal, as do other actions such as the creation of a Small Farm Operation certification program. To meet US Environmental Protection Agency (EPA) water quality requirements, under a regulatory framework, the state is working to implement education and outreach, technical and finance assistance, and inspection and enforcement programs.

To work towards these goals, AAFM collaborates with the Natural Resources Conservation Service (NRCS) and works to leverage federal and state funds through the Capital Equipment Assistance Program (CEAP), the Farm Agronomic Practices Program (FAP), and other programs.

The state is also working to advance processes that recognize and quantify the voluntary efforts of farmers exceeding RAPs and/or implementing best management practices (BMPs). AAFM entered into a grant agreement with Newtrient to develop a preliminary model of an eight-step process to certify practices on a farm that reduce P and could generate credits to be traded or sold.

The Vermont Environmental Stewardship Program (VESP) is a voluntary program that adopts a holistic, comprehensive view of environmental quality standards and provides incentives to farmers through social-based recognition.

Questions and comments from Working Group members *(direct responses from AAFM staff are in italics)*

- Are you suggesting the Working Group make RAPs the baseline for a PES program?
    - *The program will ensure that water quality standards are met throughout the state. Setting enhancements or incentives beyond RAPs may be best. This could be done either*

[1] See slides found at https://agriculture.vermont.gov/pes for additional detail.

through a temporal difference to incent the achievement of water quality standards faster, or by setting standards past RAPs.

- The additionality beyond RAPs could either be implementation of different practices, or implementation of RAPs practices to a higher standard.
    - *There is no standard for soil carbon or organic matter. Different metrics that are discretely regulated in RAPs, or soil erosion rates, could be options. It would be important to set goals past RAPs standards.*
- What portion of farmers are in compliance with RAPs? What happens if they are not compliant?
    - *Of assessments done thus far, there is a 67%*[2] *compliance rate. Since certified small farms are a new area of regulation, we are two years in to a seven-year process to assess small farms. The goal of enforcement is to fix the problem. Farmers must develop plans to implement practices.*
    - *The Revised Secretary's Decision outlines a compliance schedule whereby farms under the decision would be given one year to fix one problem, and 10 years to address all other issues. If there is not sufficient financial assistance, they may be granted an additional five years, since the costs can be high. The Agency's WQ Enforcement process has a much shorter timeframe for compliance than 10 years.*
- Are RAPs measuring practices or performance?
    - *Both. A lot of discretion is left to farmers—e.g. the no discharge requirement. However, requirements are more prescriptive in some contexts, such as the requirement for cover crops in the floodplain.*
- What other baselines can we draw on besides RAPs, considering that only some metrics are tied to erosion and water quality?
- What about certified small farmers that have not yet been certified? Will they be ineligible for PES?
- RAPs have come about in response to producers using or exploiting natural resources to create a single commodity. However, we are interested in whole other ways of stewarding the land and reaching goals such as climate resilience, clean water, clean air. We should consider a focus on the metrics and desired outcomes, rather than getting bogged down in the details of baselines for the process.
    - *The holistic perspective for lands is important. Using a baseline of what is already required is helpful from an efficiency perspective given finite resources to avoid "paying twice."*
- As we consider services beyond reducing P, the complexity will increase regarding what baselines to use.

[2] The compliance rates for farm production areas specifically, based on Agency of Ag inspections of farms in the Lake Champlain Basin from 7/13/2016 – 7/16/2019, is that the production area compliance rate for SFOs, CSFOs, MFOs and LFOs inspected in the Lake Champlain Basin by AAFM is 67%.

In SFY 2018, the AAFM Water Quality Division completed 652 inspections or investigations of farms throughout Vermont and issued 101 enforcement actions to farms.

Considering a framework for a Vermont PES program

Taylor Ricketts, Gund Institute, UVM, provided a review of ecosystem services (ES) and PES concepts, discussed key design elements, and shared an initial proposed design for a program developed by members of a graduate course he taught.

Defining and conceptualizing ecosystem services

Taylor provided the following definition for ecosystem services: “The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life” (Daily 1997). ES are generally grouped into four categories: cultural, provisioning, supporting, and regulating. Ecosystems provide bundles of multiple services. Ecosystems and species contain forms of natural capital (e.g. healthy soil, forests, etc.) which allow the ecosystem to function. ES are those functions which benefit people. By adding other forms of capital, people may amplify the benefits provided and may glean value from the ES.

Those who supply the ES (or those whose land provides the service) are not always those who benefit. The benefits may be monetized, but could also be measured in satisfaction, avoided hospitalizations, or other benefits.

Key concepts of payments for ecosystem services

ES often provide public goods, but they are influenced by private decisions. The market often externalizes these benefits and does not provide for ES effectively. Regulation can address this problem by requiring practices to mitigate pollution. Incentives (i.e., PES) can be used to motivate farmers and landowners to act as environmental stewards.

A formal definition of PES contains five components:

1. A ***voluntary*** transaction where
2. a ***well-defined*** ES (or a land-use likely to secure that service)
3. is being ‘bought’ by at least one ES ***buyer***
4. from at least one ES ***provider***
5. if and only if the ES provider secures ES provision (***conditionality***)

PES proposal for Vermont

There are a number of key questions to answer in designing a PES program. Members of a graduate course Taylor taught developed a proposal for a PES program for the state, addressing key design questions in the following ways

I. *What are the goals of the program?*
   a. Measured contributions to environmental goals
   b. Enhanced farm viability and public trust
   c. Voluntary and equitable participation
   d. Innovative and sustainable agriculture

II. *What ecosystem services will be involved?*

They selected P retention and carbon sequestration as the primary services to target, considering that these outcomes are closely linked to the state's comprehensive energy plan and EPA TMDL requirements.

III. *How will we measure them? Practice or performance?*

They determined they would measure services based on performance rather than practice, for several reasons

a. Focus on outcomes
b. Encourages innovation
c. RAPs already exist
d. Uncertain effectiveness of practice-based.

They acknowledged risks of a performance-based approach: it is more complicated, potentially costly, and practices aiming to achieve performance may not work.

They proposed that measurements could be made on a "farmgate" basis, measuring whole farm nutrient balance by gauging total P imports to and exports from a farm, and/or by using the state's P index (which has the benefit of using existing data and being supported by Extension.)

IV. *Who gets paid and how much?*

The class proposed that payees must be in compliance with RAPs and would receive an average of $10-100/pound P/year. Payments would be differentiated based on farm size and location, acknowledging that P reductions are more valuable/needed in some locations and that larger abatement costs may be faced by smaller farms.

They proposed upfront payments to incentivize enrollment, followed by annual payments based on performance. They proposed an initial baseline would be calculated by average P levels for the three years preceding enrollment. They also discussed the possibility of using RAPs as a baseline.

V. *Who pays?*

The class suggested a publicly funded model.

- Option 1 would reallocate current funding sources. This would require considering the cost effectiveness of PES versus other existing programs in reducing P.
- Option 2 would expand funding sources. This would require assessing the political feasibility of expanding sources (e.g., is a new tax a viable option?)

VI. *Who will administer the program?*

The class determined an intermediary between the public beneficiaries and farmers should be trusted by all stakeholders and experienced in administering conservation incentives. They discussed the possibility of empowering an existing entity, and posed as potential options: Vermont Housing and Conservation Board, Vermont Land Trust, or Natural Resources Conservation Service.

VII. *How do we balance fairness and efficiency?*

The class acknowledged a central tradeoff between rewarding past good behavior (e.g. of early adopters of ecological practices) and maximizing environmental improvements (by targeting those with most room for improvement.) They suggested the differentiated payments and use of baselines as key levers to balance this tradeoff. They also suggested that seeking equity can improve efficiency by increasing participation and support for the program and enhancing legitimacy.

Questions and comments from Working Group members *(direct responses from Taylor are in italics)*

- Overlapping benefits are complex. How can we assess the value of a broad array of ES, especially if they overlap? Will social and cultural ES be included in what this Working Group considers?
  - *Often each benefit has its own buyers. They are sometimes sold individually and are sometimes bundled together. The specificity or fuzziness of each approach come with tradeoffs.*
- All four models of ES benefits (cultural, provisioning, regulating, and supporting) are relevant and will financially benefit the farmer.
- Who pays matters. Who pays for the costs to land, people's health, and society at multiple levels of producing items like high-fructose corn syrup is different from who pays for organic beef. We're all paying for the damages of products like high-fructose corn syrup through the production and consumption cycle, whereas only a few of us are paying for all the benefits of organic farming.
- How can the metrics discussed account for agronomic practices to improve soil biology to reduce P contributions?
  - *This can be accounted for the in farmgate model where, for example, how much P-laden feed needs to be trucked in. This can provide an incentive to disrupt problematic supply chains.*
- Some of what is called performance seems to be a more refined practice model. There is a balance between practice and performance, but either type of measurement costs money.
  - *Some metrics are an attempt to walk between practice and performance by accurately predicting performance from practices in specific land contexts.*
- We should measure what is actually happening rather than model it based on research. Biology is always adapting and changing. The saying "all models are incorrect; some are useful" is apt. It would be helpful to identify one thing or a small number of things to measure from which all other necessary improvements flow. I would posit the structure and structural integrity of soil could be that metric. Clod tests or infiltration tests could be useful metrics in this regard. It may be more efficient to measure and reward the creation of natural capital.
- Soil health is also a useful metric because it benefits the farmer. Something that benefits the farmer is helpful because it may mean that payments are not required indefinitely if they ultimately are beneficial enough to the landowner/farmer.

Vermont Environmental Stewardship Program (VESP)

Judson Peck, AAFM Water Quality Division, provided an overview of VESP, reviewed the VESP pilot study, and discussed the possibility of VESP administering a PES program.[3]

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[3] For more detailed information on VESP, including information about the assessment tools it uses, see slide found here: https://agriculture.vermont.gov/pes.

VESP overview

VESP's goal is to accelerate water quality improvements through additional voluntary efforts and provide recognition for farmers who strive for environmental excellence. It currently provides social recognition to program participants, but could potentially provide financial payments in the future.

The program's development began in 2013, with funding originally coming from an NRCS Vermont Conservation Innovation Grant. AAFM, Department of Environmental Conservation (DEC), USDA Natural Resources Conservation Service (NRCS), Vermont Association of Conservation Districts (VACD), and University of Vermont Cooperative Extension (UVM) partner on the program.

To be eligible to participate in VESP (which is a voluntary program), farms must

- Be actively farming in the state
- Be a farm size as defined in the RAPs
- Submit all land managed by the farm, whether owned or leased, to assessment and certification
- Meet existing regulations, including RAPs

Assessment and tools

Participating farms are assessed according to the following criteria using the NRCS Resource Stewardship Evaluation Tool (RSET) and the Cornell Comprehensive Soil Health Tests.

- Nutrient management
- Sediment and erosion control
- Soil health
- Air quality
- Carbon sequestration
- Pasture health

RSET streamlines the assessment of multiple resource concerns in an integrated tool: soil management, water quality, water quantity, air quality, and wildlife habitat. It evaluates site-specific risks and applies thresholds to meet a unified national target (i.e., higher-risk fields require a higher level of stewardship to meet the national target.) The Cornell tool is a comprehensive test that measures multiple indicators of physical, chemical, and biological soil health.

Process

Farmers who meet baseline RAPs may apply to VESP. VESP contracts with conservation planners who conduct the farm assessment. If the farm does not meet the thresholds established in the RSET and Cornell Soil tools, the farmer works with the conservation planner to develop a conservation plan. If thresholds are met, the farm receives the VESP sign and is certified for five years. Follow-up monitoring is conducted and farmers may reapply for additional certification periods.

Pilot study

VESP is currently conducting a pilot with 10-12 diverse farm types to vet the process and assessment tools. The majority of farms tested so far in the pilot are doing quite well relative to the threshold indicators of both tools.

VESP and PES

VESP is a nearly full functional program, currently in a pilot, that provides a framework to objectively quantify multiple ES.

Act 83 of 2019 of the Vermont General Assembly, which called for the creation of this Working Group, identifies similar goals to those identified in Act 64 of 2019, which called for the creation of the Environmental Stewardship program. Namely, they seek to

- Improve soil health
- Enhance crop resilience
- Increase carbon storage and stormwater storage capacity
- Reduce agricultural runoff to waters

Additionally, there is good alignment on principles between VESP and best practices for a PES program:

1. Voluntary – participation based on additional benefit of PES program; no legal requirement
2. Beneficiary Pays – land managers are stewards (not polluters)
3. Direct Payment – beneficiary (public) to provider (land managers); or through intermediary (VAAFM)
4. Additionality – provision of services not occur without PES program (pay for additional services)
5. Conditionality – payment dependent on delivery of services

In the current VESP program, there is no baseline (e.g. reducing from a three-year average of P loads.)

AAFM submits to the Working Group for consideration the possibility of building on or incorporating VESP into a PES program.

Questions and comments from Working Group members *(direct responses from AAFM staff are in italics)*

- What are you testing in the pilot? Are you actively checking farms?
  - *Part of the effort is to calibrate the standards. If all farms easily pass, maybe the threshold is too low.*
- How significant is the social recognition alone to farmers?
  - *A number of farms reached out to VESP to express interest. Social recognition is important, though financial compensation would obviously be preferred. VESP has the authority to manage payments, though it does not have a means or methodology to do so currently.*
- Should there be financial incentives lasting five years that a producer can obtain from a snapshot assessment done in one day? Perhaps other assessment tools that provide more ongoing accountability should be considered. For example, there are technologies using satellites to measure growth every day.
  - *Annual spot-checking & verification of implementation is a part of maintaining VESP Certification and is built into the framework for the full VESP program.*
- How much could VESP be adapted in response to what this group develops for measurement, methodology, etc.?

    - *This program is flexible and still in pilot. Use of RSET aims to balance accuracy and costs, but other technologies could be considered.*
- Could the program accommodate a lot of farmers who wanted to join?
    - *The pilot is evaluating how much work evaluation requires, particularly for larger farms.*
- Does VESP show additionality, e.g. requirements to go beyond RAPs?
    - *It varies by field and by farm, since requirements are dependent on site-specific risks.*
- An expanded pilot could answer some additional questions and test some other tools.
    - Vicky Drew, NRCS: RSET is not that flexible of a tool. Moving the threshold for water quality is something we have been discussing and the developers could modify for Vermont.
- Does the VESP soil health test capture the soil sponge/soil structure and integrity metric? Mass balance could be added to VESP if so.
- BMPs and the RSET assessment tools are helpful to prevent further erosion of soil capital, but they may not incentivize the building of natural capital. We need to think creatively about different tools and technologies available to incent a shift from tolerable soil loss to building healthy soil. VESP seems to be acknowledging something less bad, rather than outlining where we want to go. It looks like most thresholds are met already.
- The 3 lb. P/acre national number should be translated into a Vermont number.

Meeting reflections: weighing options and key design considerations for a PES program

- The group has several options:
    - Fill out the matrix "homework" and then mix and match options
    - Develop an approach focusing on soil/natural capital
    - Use VESP as a scaffold on which to attach baseline values, determine eligibility, relationship to RAPs, etc.
    - Farmgate model (suggested by UVM students)
- Among key design questions, there seems to be relative consensus on measuring performance.
- It is possible to pay for good baseline levels for those who have adopted good practices, while also paying for additional improvements.
- Equity improves efficiency. This was reflected in hearing from farmers during legislative sessions that they want to be sure those who have been doing it right all along will be rewarded.
- The Working Group should imagine would communities, landscapes, economies, budgets, quality of life would look like with robust soil capital. This is a different approach than identifying benchmarks.
- What would be a "baseline" for natural capital? Would it be BMPs, a score on RSET, etc.? How would we incentivize the construction of more natural capital?
- How could a program allow farmers to get recognition and differentiate themselves in the market? Rewards in the marketplace could help replace transitional payments.
- A challenge with relying on product differentiation is that, once market penetration is reached, the price does not hold. We are also seeking a model that recognizes that the benefits are public goods. If farmers were paid an adequate price for their products, there would be no need for PES, but then only milk purchasers would be paying for it. By hoping that the marketplace will pay the price for the service, we're stuck in the "maximizing product" paradigm.

Public comment

- Andrew Davis, Northeast Organic Farmers Association Vermont: Measurements should reflect a sustainable ecosystem, not just the value the ecosystem provides. Otherwise, we risk getting stuck in the same paradigm of seeking high "productivity" on a metric, which may not be sustainable. Farmers are part of the ecosystem. If we incentivize decreased production of a commodity on a farm in favor of another ES, that may externalize the production methods into something out of control of the system, which could be less sustainable than the current production was.
- Brian Beckage, UVM: The VESP option sounds expeditious. I am concerned about the variability from a one-time snapshot. Also, how does a well-managed farm translate into quantifiable ES? For carbon sequestration, why not link to existing external markets for carbon offsets, etc. rather than creating a new market internal to Vermont? For P, what does 3 lb./acre of P removed translate into for downstream effects?
- Phil Huffman, The Nature Conservancy (TNC): TNC advocated for the creation of this group. We are heartened to see it has been created and to hear this discussion. TNC has been involved nationally and globally in efforts to develop PES frameworks. We hope this could be a resource to you. We support the overarching goals of moving towards enhanced environmental outcomes on critical farm resources, and recognizing support of farmers for environmental outcomes.
- Abe Collins, Landstream: the most viable path forward is to hire farmers to rebuild the natural capital we used to build Vermont. As important as measuring performance is the ability of land managers to use feedback to gauge their efforts. One ES is nutrient retention. A lot of P will be needed to increase organic matter one foot of depth.
- Abbey Willard, AAFM: The group could consider product differentiation for Vermont farms that participate in PES. It could have social value and eventually, through a customer base, financial value.
- Lauryn Sherman, VLS Student: We need to move beyond old models that seek to minimize damage, and instead seek actual regeneration of natural capital.
- John Winsten, Winrock: the focus on soil health will have private benefits for the farmer, and won't require a perpetual subsidy. On the other hand, if the ES requires a cost to the farmer, a program has to keep paying the cost or it won't realize the benefit.

Working Group attendees

1. Jill Arace
2. Paul Doton
3. Vicky Drew
4. Alyson Eastman
5. Nancy Everhart
6. Eric Howe
7. Brian Kemp
8. Maddie Kempner
9. Didi Pershouse
10. Taylor Ricketts
11. Chuck Ross
12. Marli Rupe
13. Tyler Webb

Vermont Soil Health and Payment for Ecosystem Services (PES) Working Group

Waterbury, Vermont
October 21, 2019 Meeting Summary

Next steps

- AAFM will post meeting materials and webinar recordings to the website.
- AAFM will compile and calculate sources and amounts of current funding being spent on water quality issues.
- CBI and AAFM will explore potential future webinars, including:
    - Landstream – discussion of monitoring and modeling technologies
    - Ecosystem Services Market Consortium
- CBI and AAFM will investigate resources and expertise to help quantify the costs of inaction and costs avoided through the provision of ES.
- CBI will work with WG members to begin to capture stories to help illustrate the experienced benefits of soil health, to be used in the narrative of the group's report.
- CBI will revise the September meeting summary to clarify statements about VESP requirements. The summary will then be considered final.
- CBI will revise the ground rules document to clarify that more than one alternate per seat is permitted if necessary.

Summary

The Working Group (WG) reviewed a matrix of design criteria and possible options for a PES system to discuss the pros and cons of various approaches and generate additional options. The content of the matrix was based on ideas and priorities for a PES system that WG members articulated in their responses to a survey. The WG then delved into more detail on several key questions in small groups before reporting back to the full group. Members' comments are summarized below.

Should we build on what we have or consider whole cloth change?

In support of a phased approach:

- We are not yet paying for performance that goes over and above minimum requirements. In the short-term, we should build on what we have and then in the longer-term do a more radical rethink of the system. Public awareness and support and funding would be needed for a more ambitious proposal. In the short-term, we should be pragmatic about how to target a likely small initial funding pot from the legislature.
- To get to the systemic reforms desired, we should take a first "pilot" step of building on the tools and regulations we currently have.

In support of fundamental reform:

- Significant reform is needed. A proposal to build on what we have and build on the baseline of RAPs is in some ways designating a tolerable level of degradation and loss of soil. Rather, we should orchestrate the shift from exploitive practices to generative ones in which we pay for the building of natural capital.

- This is expensive and requires the state to be a significant customer. It will also require creative thinking to integrate public and private sources of funding, plus consideration of the possibility of trading internationally. The framework established could facilitate the electronic trading of commodities. The focus should be on creating the pathway for this market.
- At this point considering the state of farming, dairy, land quality, and climate change concerns, we need to take the risk to build a new program. This may initially involve filling in the gaps in the current framework, but requires us to change the system pathway to reverse the degradation of soil health and natural capital.
- We should avoid the risk of standing up something modest that could preclude the option of revisiting and creating a more ambitious plan later.

Considering short time frame, choose something achievable:

- Considering the short time-frame of this group's work, we should recommend small scale pilot evaluation efforts to answer questions this group identifies, including the effectiveness of shifting from practice- to performance-based approaches. We could report to the legislature what the group resolved and what it hopes the pilots answer. This information could inform recommendations for more systemic change.
- We should choose something achievable and that the legislature will implement.
- If this group created a pilot, the legislation would likely build in a sunset clause for when the program would end and be revisited for review and potential improvements. This work will not be completed quickly and this group may continue to meet.
- The final recommendation of this group should be to provide adequate funding and time for a compensated, more technically advanced group to fully address these questions.

What ecosystem services should be included?

Targeting soil health and soil capital, while incorporating measures to address nutrient issues:

- An approach to compensate for soil health improvements could be combined with compensation for the management of nutrients.
    - Considering the amounts of P that are imported and can't be assimilated, we may want to think about the specific questions of whole farm balance to deal with near-term nutrient issues. Soil health metrics do not alone measure nutrient management metrics, but by putting them together we could keep our eyes on the immediate nutrient problems while still identifying big mechanisms of change.
- If our pilot encompasses payments for soil or natural capital, we should be clear about what benefits and what "stock" we are paying for.
- Our nutrient problems are a result of poor management practices over many decades. A narrow focus on nutrients is using a snapshot view to attempt to find solutions to address a long-term issue. Nutrient issues should not be ignored, but a more fundamental shift to encourage land stewardship and rebuilding natural capital is preferable.
- We should test a pilot approach focused on soil/natural capital to help answer what we can measure, what benefits flow from those outcomes, and how much we can pay. If we can use this test to learn more, it would have the benefit of being simpler than enumerating many different benefits we want. For example, we need to test for the relationship between soil health and nutrient management. Considering the TMDL on P, we need to be able to

demonstrate that a soil health-focused approach deals with the P issues that are a focus of the legislature.

On whether a more comprehensive suite of benefits should be included:

- A comprehensive approach to measure for multiple benefits such as pollination, habitat, and others in addition to soil health would be too much to take on at once.
- If we create a trading framework focused on natural capital, adding in other benefits such as pollination and wildlife habitat—which already sees substantial investment from organizations and the public trust—could be done without too much added complexity.

What is being measured and how? Establishing metrics and determining measurement tools

- Other metrics such as hydraulic conductivity, infiltration, soil aggregate stability, and photosynthetic activity help provide a fuller picture. Tools such as satellite measurements of UV radiation, remote sensing, soil mapping, and others can help provide a fuller picture for some cases. Soil scientists with more expertise than is represented on this group could help address the metrics needed.
- If there is funding for farmers to generate natural capital, private industry will fill the need to develop measurement technologies.
- We should avoid creating something so intricate that it is unintelligible to most people. It has to be simple enough to understand and not prohibitively expensive to measure.
- Avoided costs, such as protections for infrastructure from flooding, should be factored into benefits measured. More data to determine metrics for these may need to be gathered in a pilot. Quantifying avoided costs would be powerful to persuade the public and the legislature.
- Outcomes, rather than practices, should be paid for.

Program design and eligibility

Program creation considerations

- Building on VESP as an existing program would provide flexibility and would not require new rule-making, which was hard fought for VESP.
- Could an RFP process by initiated for bids to run a pilot project of some kind?
- Would a program make any funding available upfront to help with startup costs?
- Any program should make clear that it is not a handout or a subsidy, and that farmers are being hired to provide services. It should also acknowledge that farmers currently provide ES, including doing more than any other sector to address water quality issues.

Creating a market

- Some farmers may not capitalize on an invitation to participate in a less structured market and would be more likely to participate with clearer direction and a program to participate in.
- This group should focus on creating a pathway for the sale of ecosystem services, not a program. The state could commit a quantity of funding to purchasing natural capital and additionally provide funding to technical assistance providers to work with farmers, including VHCB, NOFA, and others. A small pilot targeting a particular watershed with high ambition and high potential for benefits could demonstrate the validity of the services and then potentially be

expanded to a much larger scale in the form of a market. An industry would then spring up to support farmers to participate in the market.

  - Markets need help to get started. The beginning stage of a market can look like a program, which can help establish consistency for and confidence in what benefits are provided, how they are measured, and that investments are worthwhile.
  - It could prove challenging to create private markets for public goods. Additionally, could the design mitigate the potential for the market to drive the price down for these goods, making it less worthwhile for farmers?
  - Ultimately, a funding stream could be secured through a conservation tax that everyone is subject to, with a resource tax for those who do not meet certain standards for stewarding the land.

- There is opportunity to learn from existing markets globally. This process should avoid reinventing the wheel.
  - There are parallels to learn from in the forest carbon market.
- Building a market requires understanding what stimulates behavior change.
- Would services be stacked or bundled in a market? How could multiple payments for the same thing be avoided?
- Care should be taken to make sure that whatever form a market takes, it is equitable across scales.

What baseline should be established for eligibility? Is there a minimum threshold?

- A baseline is needed to know what is being paid for and to ensure that what is being paid for is "new."
- Statute language states that to be eligible for programs, farmers must be in compliance with RAPs or be in good standing, demonstrating that work is being done to fix the out-of-compliance issues.
  - Could RAPs be an eligibility requirement, though perhaps not an appropriate baseline?
  - Could compensation be offered only for what exceeds RAPs?
  - Don't worry about RAPs for eligibility for PES opportunity. RAPs are required practices, separate from consideration of a PES system.
- There is a gap between the RAPs and achieving the TMDL. PES could help farmers meet RAPs and TMDL.
- While separate sources of assistance are available to meet RAPs, the group should be mindful about how available resources for meeting RAPS compare with compensation for ES. Significant environmental benefits (such as water quality) can be gained by bringing farmers into compliance with the RAPs.

Public comment

- Other metrics that may be considered in calculating ES provided include: diversity of plant species, biodiversity, photosynthesis, stream peak flows, algae blooms, and others.
- One concern regarding creating a market is market collapse. Some services are not easily monetized and where benefits are hyperlocalized, for example in avoiding roads washing out, a large-scale market would not capture these. In some cases, hyperlocal sources of funding would be helpful.

- Services should not be calculated based on one metric such as P retention or carbon sequestration. There are methods to measure benefits more comprehensively, which involve using a range of observed and modeled metrics.
- There are other programs that are focused on nutrient management and meeting the TMDL. A PES system should address positive gains, not only pay to mitigate the problem.
- This group should have a broader focus on natural capital rather than just nutrient management. The group should be realistic about what can be achieved in this timeframe, but create something that can be expanded with time.

The meeting was adjourned at 2 PM.

Working Group members in attendance

1. Jill Arace
2. Cat Buxton
3. Paul Doton
4. Alyson Eastman
5. Nancy Everhart
6. Brian Kemp
7. Taylor Ricketts
8. Chuck Ross
9. Marli Rupe
10. Tyler Webb

Vermont Soil Health and Payment for Ecosystem Services (PES) Working Group

Williston, Vermont
November 15, 2019
Meeting Summary

Next steps

- AAFM will post meeting materials, webinar recordings, and the October meeting summary to the website.
- AAFM will share public comments received via email with the Working Group
- CBI will work with the cochairs to develop components of a draft report
- CBI will plan future webinars, including one with Newtrient and potentially one on NRCS.

Summary

The Working Group's discussion focused on further elaborating PES program design criteria for a demonstration project; considering the applicability of and transferable lessons from related tools and projects, including the Conservation Effects Assessment Project (CEAP), the Resource Stewardship Evaluation Tool (RSET) and the Cornell Soil Health Test (CASH); and providing feedback regarding the direction and outline of a draft report.

Program Design Criteria

The group continued its discussions to refine a potential demonstration project. Key questions surfaced and options considered included the following:

What are the advantages and disadvantages of disaggregating the water quality benefits from other ecosystem services that may be provided by soil health, such as flood mitigation?

- Beneficiaries of the water quality benefits are more broad-based, whereas the flood mitigation benefits are likely very localized. Therefore, likely payers could be different.
    - What role could municipalities play? Given municipal investment in flood mitigation, could municipalities become buyers of flood mitigation benefits?
- Improving flood mitigation is a significant part of managing nutrient runoff.
- Valuing soil health in an integrated way may be a key component of the paradigm shift sought by this group, as compared to a more siloed approach to ecosystem services.

The relationship between soil health and nutrient retention is not yet well established. Multiple metrics to measure soil health may be needed to capture the aspects of soil health that this group is interested in measuring and valuing.

- For example, if the CASH test is primarily measuring the capacity to produce viable crops, it is not yet clear if a certain threshold level on the CASH score (e.g. a high score such as 90) also implies significant nutrient retention benefits. One possible question a demonstration project could help answer is what CASH score, if any, indicates that the soil provides water quality (nutrient retention) benefits?

- Could the nutrient management requirements of required agricultural practices (RAPs) address the question of overapplication of amendments/manure that would not be captured by a CASH score?
  - For fields with a medium or low P risk, farmers can apply above crop removal for P and still meet RAPs and pass RSET. There is latitude within existing regulations to build soil health with manure while being compliant with P loss standards.
- If a field is passing in RSET, is it very likely to be meeting the RAPs? If this relationship could be established it could provide efficiencies by avoiding the need for a state visit.
  - RSET does not look at production area compliance, which is a part of RAPs.

Given that much of the demonstration project may be focused on gathering information and establishing the relationships between soil health and desired ecosystem services, how should the project be structured?

- Payments:
  - Could farmers be paid some fixed price for participating?
  - Could graduated payments be made for the quality of natural capital provided as the work is done to calibrate the relationship between quality of natural capital and the desired ecosystem services?
- Since the VESP program includes RSET and CASH, could a payment element simply be added, and learning questions be defined that can be answered by the data gathered by VESP?
  - Where is the verification in such a model? CASH is more focused on healthy crops, and RSET is based on models and is only focused on a limited array of conservation practices meant to limit further degradation of resources rather than more generative practices.
  - The tools VESP uses are not articulated in the statute, so they could be changed.
- Consider focusing on one key watershed, such as the Winooski, South Lake Champlain, or Rock River.
- Avoid creating another program in which farmers can enroll. This should be a focused effort to correlate the relationship between soil health and desired outcomes.

What other issues need to be resolved before proceeding?

- How can measurements avoid penalizing participants for outside influence on their farm? If an upstream neighbor is polluting, how can that be considered?
- To get the statewide buy-in needed to advance a program, it must demonstrate relevance and benefits for the eastern side of the state.
- Natural capital or soil health, once well defined, could be an alternative to paying for practices or performance purely. While the natural capital model is attractive, it may not capture all the benefits the group wants to generate, so other things may need to be measured and paid for as well.
- We need to be mindful that complexity in the program can be a barrier to participation for farmers. Additionally, if the bar is set too high, many farmers will be unable to participate.

  - Creative funding options beyond general funds from the legislature should be explored, including impact investment, low-cost forgivable loans, sponsorship money, and others.
  - If this Working Group were to continue, how can we engage more farmer input going forward?

Watershed Monitoring and Conservation Effects Assessment Project (CEAP)[1]

Joshua Faulkner, UVM Extension, presented an on overview of CEAP watershed assessment studies. The watershed assessment studies are tightly linked to NRCS programs and focused on understanding the aggregate impact of programs implemented on the watershed scale. CEAP uses a paired watershed experimental design. It begins with a calibration period of the pair, and then a treatment period with the implementation of conservation practices in one watershed and business as usual in the control watershed to monitors differences across the pair over time.

Questions, comments, and discussion *(direct responses from Mr. Faulkner are in italics)*

- *The infrastructure costs approximately $18,000 per station, and total costs are around $300,000 per station for six to seven years.*
- *The project is not currently using CASH tests.*
- We need to be able to quantify the soil reconstruction value for water quality. There is a lot still not well understood. Some conservation practices can result in more runoff, though some of those conservation practices may not actually be improving soil health as this group conceptualizes it but are rather seeking to compensate for the lack of qualities that healthy soil provides (e.g. slit aeration trying to compensate for lack of infiltration ability that healthy soil would provide.)
- How is research such as this being used to set objectives for the TMDL?
  - Ryan Patch, AAFM: Whenever the RAPs are amended, the AAFM reviews research and information available. Rules are supported by documentation of research that can demonstrate the efficacy of regulations and are vetted by the public and committees.
- What treatment practices are of the highest interest? Where else are paired experiments happening like these?
  - *The project has learned a lot from Ohio, where a lot of work is being done. With more no till, we saw improved soil health. This resulted in a decrease in particulate P loss, but an overall increase in soluble P loss. These results are confounding. Tile injection is of interest to explore.*
- This program seems geared towards tweaking the traditional conservation programs we have now. It seems relevant for information exchange to guide stewards who may need that help rebuilding natural capital, though not sufficient alone to get us on the path to the ambitions of this group. Linking this project with CASH to monitor soil growing practices could help test the idea that a well-structured, functional, chemically active, and biologically diverse soil would create the outcomes we are seeking.

[1] For details on Mr. Faulkner's CEAP presentation, see the presentation slides posted at https://agriculture.vermont.gov/pes

Resource Stewardship Evaluation Tool (RSET) in Detail

Judson Peck, AAFM, provided an overview of RSET to give additional detail about the tool, building on the introduction provided in the VESP presentation at the first Working Group meeting[2]. RSET is an online web-based tool developed by NRCS. RSET

- Streamlines multiple tools into one integrated tool
- Is a holistic assessment across multiple natural resource concerns
- Is compared to science-based thresholds set by NRCS
- Incorporates site-specific data of each field (slope, soils, climate)
- Incorporates nutrient application data of P-Index
- Models management and practice changes – farmer see effects and plan accordingly

RSET incorporates five resource concerns: soil management, water quality, water quantity, air quality, and wildlife habitat. It determines the appropriate threshold specific to characteristics of the site to meet a national target.

The group discussed the interactions between RSET, CASH, and other metrics including the P index and observed that though there is some overlap in the metrics of these tools, a field could score well on one while poorly on another. The group discussed the possibility of using CASH and RSET in combination for a demonstration project, as the VESP program does. For example, the group discussed that RSET may be able to capture some dimensions around nutrient management plans that CASH may not address.

NRCS Programs

Vicky Drew, NRCS, provided a brief overview of NRCS programs that may be relevant to the efforts of the Working Group including EQIP, CSP payments, and the RCCP program. She mentioned that Congress directed NRCS to look further into ecosystem services and that this topic could rank more highly in future grant rounds. She mentioned that an RCCP alternative funding mechanism would likely come out in winter or early spring 2020.

Public Comment

- Tom Berry, Office of Senator Leahy: The opportunities laid out by Vicky Drew from NRCS may be the best way to seek federal support in the near term, since there will not be a new farm bill for five years.
- Tom Stoddard, Native Energy: I encourage the group to consider non-farm providers of ecosystem services in the development of a PES program.
- Erica Campbell, Office of Senator Sanders: I encourage the group to look at a new report out on climate change looking at current and potential federal programs *[need reference to report.]*
- Matt Gardner, AAFM: Regarding the discussion of decoupling water quality from flood mitigation: other than stream erosion, those are largely the same thing since flood mitigation is a primary driver of water quality improvements for nutrients going into the lake.
- Graham Unangst-Rufenacht, Rural Vermont: I encourage the group to keep the emphasis on natural capital and landscape function. Soil requires healthy plans, and plants require healthy animal management.

[2] For details on Mr. Peck's RSET presentation, see the presentation slides posted at https://agriculture.vermont.gov/pes

- David Miskell, Real Organic Project: I encourage the group to make sure that the pilots that are suggested by this group have broad enough political support and that you consider where they are located when determining this. This effort is critical to organic farmers, among others.

Working Group Attendance

1. Jill Arace
2. Cat Buxton
3. Paul Doton
4. Vicky Drew
5. Alyson Eastman
6. Nancy Everhart
7. Eric Howe
8. Neil Kamman
9. Maddie Kempner
10. Taylor Ricketts
11. Chuck Ross
12. Tyler Webb

Vermont Soil Health and Payment for Ecosystem Services (PES) Working Group

Williston, Vermont
December 16, 2019
Meeting Summary

Next steps

- AAFM will post meeting materials, webinar recordings, and the November meeting summary to the website.
- CBI will revise the draft report per comments from the WG and develop a draft budget proposal for WG review at the January meeting

Overview

The Working Group's discussion focused on refining the draft interim report to the legislature and brainstorming a prospective workplan for continued efforts into 2020.

NOFA-VT Farmer Survey

Maddie Kempner, NOFA-VT, shared preliminary results of a survey of farmers in the state that she and a small group developed to gain input from small-scale farmers whose interests NOFA represents on the Working Group. Maddie identified the most common themes that arose from the survey responses, including encouraging pasture/perennial forage, ensuring financial viability for farmers, supporting small-scale farming, improving clean water, and reducing nutrient and pesticide inputs into the system. The preliminary results indicated substantial engagement and interest in the topic of PES among farmers, and also the need for more education about PES concepts. All Working Group members had the opportunity to circulate the survey to their networks. Because most respondents were engaged through NOFA and the Vermont Healthy Soils Coalition's networks, the respondents were primarily from small, diversified farms.

Comments and discussion

- Group members were interested in extending an invitation to the survey to a larger and broader community of farmers. The group agreed to keep the survey open and give an opportunity for more responses to be gathered.
- Group members cautioned against extrapolating too much from the survey in the absence of any other community engagement information, since the survey was not conducted scientifically and the responses were not a representative sample.
- The group expressed interest in potentially doing a more rigorous, scientific survey in the future.

Revising the draft interim report to the legislature

Much of the meeting was focused on Working Group members providing input a draft of the interim report to the legislature. This feedback is captured in the revision to the report circulated before the January 9, 2020 meeting.

Public comment

Several members of the public made comments, including suggestions for revisions of the report:

- Phil Huffman, The Nature Conservancy: the charge to the Working Group from the Legislature reinforces the point made in discussions here that soil health is an important factor, but not the only item on which this group should focus. Additionally, it may be helpful for the report to articulate key principles for what a PES program needs to include on which this group agrees, such as outcomes rather than practices, voluntariness, additionality, quantifiability, verifiability, durable outcomes, and others. A clear definition of soil health should be provided. Notably absent from the Working Group is a representative from the environmental/NGO community. The Nature Conservancy may be a useful addition to these discussions. The concept of a pilot effort in the short term coupled with a longer effort to build a full strategy seems wise.
- Abbey Willard, VAAFM:
  - it is helpful to distinguish between two phases being discussed: one focused on buying community benefits such as flood protection for local infrastructure, and the other focused on investing in a functional landscape. An additional, softer value benefit of reputation- and relationship-building is not yet captured in these discussions.
  - The Working Group should look to national opportunities, such as the Ecosystem Services Markets Consortium's announcement of plans to invest in new areas. If Vermont made a small investment to serve as the match to unlock that investment, it could be very valuable.
- Graham Unangst-Rufenacht, Rural Vermont: the emphasis on natural or soil capital should be framed in terms of landscape function. The framing as investment rather than payments is also important. More investigation of what can and cannot be measured is needed. This report needs to explain that a PES system will not be a silver bullet for the larger economic issues hurting farmers. More thought is needed on how to bring this conversation to farmers and watershed groups.
- Andrew Davis, NOFA: more in-depth reflection is needed on why current programs are not sufficient. Look to the models created in other states such as the watershed ag council in New council in New York State, where investments were made in ecosystem services to save money on water treatment. Community organizations should be involved more to allow investment in natural resources. Perhaps the state could create a matching program to make it easier to invest in ag quality.
- Chris Kopman, Newtrient: Advanced models are not simply paying for practices. Payment for practices uses a formula of x dollars tied to y acres of z practice, etc. With a sophisticated model, payments are tied to quantified outcomes, such as nutrient retention or carbon sequestered.
- Jon Winsten: Pilot testing will be essential to get precise information and uncover important questions. Consider options to pay both for transformation of the landscape and more minor improvements via tweaks to management in the short term. The uptake of many farmers may be significantly lower if the only option for participating is in a "transformation" effort.

Working Group Attendees

1. Jill Arace
2. Paul Doton

3. Vicky Drew
4. Alyson Eastman
5. Nancy Everhart
6. Eric Howe
7. Brian Kemp
8. Maddie Kempner
9. Didi Pershouse
10. Chuck Ross
11. Marli Rupe
12. Tyler Webb

PAYMENT FOR ECOSYSTEM SERVICES AND SOIL HEALTH WORKING GROUP INTERIM REPORT

Prepared as an interim, informational update regarding

Act No. 83, Section 3 (2019)
Act No. 129, Section 24 (2020)
Act No. 47, Section 6 (2021)

Submitted to the

Senate Committee on Agriculture

House Committee on Agriculture and Forestry

By the

Vermont Agency of Agriculture, Food and Markets

February 1, 2022

Payment for Ecosystem Services and Soil Health Working Group Interim Report

February 1, 2022

Table of Contents

I. PES Working Group Background

Due to the initiative of three farmer-led watershed coalitions, the Vermont Legislature enacted Act 83 of 2019, Section 3 charging the Secretary of Agriculture to convene a Working Group to discuss Soil Conservation Practices and Payment for Ecosystem Services. Between September 2019 and January 2020, the Working Group met in-person five times and held six webinars with experts and practitioners who provided resources and perspectives to aid in the Working Group's thinking about PES tools, metrics, and system design.

Following several recommendations of the Soil Conservation Practice and Payment for Ecosystem Services Working Group, as laid out in the January 15, 2020 Report to Legislature, Act 129 of 2020 amended Act 83 of 2019 to rename the group the "Payment for Ecosystem Services and Soil Health Working Group," establishing the Working Group through January 2022, to direct the inclusion of several additional seats on this Working Group, and to lay out specific charges for this Working Group. Specifically, the Legislature named the following findings and recommendations be considered and included in the Working Group's final report:

1. a recommended payment for ecosystem services approach the State should pursue that benefits water quality, flood resilience, and climate stability, including ecosystem services to prioritize and capital or funding sources available for payments.
2. a recommended definition of healthy soils, a recommended method, or systems for measuring soil health and other indicators of ecosystem health, and a recommended tool for modeling and monitoring soil health.
3. a recommended price, supported by evidence or other justification, for a unit of soil health or other unit of ecosystem service or benefit provided.
4. proposed eligibility criteria for persons participating in the program.
5. proposed methods for incorporating the recommended payment for ecosystem services approach into existing research and funding programs.
6. an estimate of the potential future benefits of the recommended payment for ecosystem services approach, including the projected duration of the program.
7. an estimate of the cost to the State to administer the recommended payment for ecosystem services approach; and
8. proposed funding or sources of funds to implement and operate the recommended payment for ecosystem services approach.

The Working Group has met fourteen times in 2021 in one and a half-to-two-hour meetings, via Zoom due to COVID-19, to advance work in preparing the finding and recommendations above. The Payment for Ecosystem Services and Soil Health Working Group (PES WG) had its charge extended through February 1, 2023 by Act 47 of 2021.

Information about the PES WG – including documents and recordings of past meetings – can be found at: https://agriculture.vermont.gov/pes

II. PES Working Group: Spring 2021

The spring of 2021 involved reviewing the 2019 work, connecting with related research projects by University of Vermont (UVM) and other initiatives like the CSP+ [Conservation Stewardship "Plus"] program idea developed by several farmers and Vermont Natural Resource Conversation Districts (NRCDs), and beginning to scope and review the charges set forth by the legislature. As requested by the PES Working Group in its report in 2020, and as directed by Act 129 of 2020, the membership of the PES

Working Group was expanded and new members began attending meetings of the working group when the Working Group reconvened on Tuesday, March 16th, 2021.

The Working Group formed three Task Groups or subcommittees to develop: 1) greater clarity on analyzing costs and benefits of soil health; 2) identifying specific metrics and components of soil health, and 3) considering program design by first analyzing existing programs and considering broad criteria for quality program design.

The table below briefly summarizes the work of the Task Groups:

Table 1: Spring 2021 Task Groups

TASK GROUP	Charge 1	Charge 2	Charge 3
Costs, Benefits, Allocation	Analyze benefits of ES including nutrient reduction, flood mitigation and carbon sequestration	Explore unit price for unit of soil health and other ES	Propose eligibility requirements
Status	*A completed matrix of soil health key components, ESG benefits and possible metrics*	*Refinement of questions for an RFP for a Technical Advisor*	*Deferred to Fall work*
Soil Health	Identify metrics that relate soil health indicators to desired ecosystem services	Develop - Soil Health working definition and which ecosystem services it provides - Unit of soil health to pay for	Develop research questions and RFP needs
Status	*A completed matrix of soil health key components, related ecosystem services, and possible indicators and metrics*		*Refinement of questions for an RFP for a Technical Advisor*
Programs	Inventory existing programs	Analyze Programs	Develop Program Definition Criteria
Status	*Matrices of existing practices, rankings, and current VT spending for these practices*	*Summary of TG review of programs, gaps, and lessons by June 23.*	*Deferred to Fall work*

III. PES Working Group: Summer 2021

Over the summer of 2021, the Vermont Agency of Agriculture, Food & Markets (VAAFM) in service of goals developed by the Working Group issued a Request for Proposal (RFP) based on the work of the PES WG for a technical consultant to support and advise the Working Group. The RFP requested the following research activities to help the PES WG fulfill the charge set out by the legislature:

- Determine metrics for quantification of ecosystem services from soil health
- Establish range of acceptable/preferred payment rates using contingent valuation
- Calculate range of full economic cost to farmer per unit of soil health metric to provide lower bound on payment rate and aid farmer decision-making
- Establish an estimate of the total value to society of soil health in Vermont agriculture
- Review and summarize existing models of performance-based programs for PES working
- Provide clarity and recommendations on crucial PES program structure issues
- Collaborate closely with the PES WG and build trust in the process, the information and the recommendations from this work.

The RFP was issued on July 26, 2021, and awarded On September 29, 2021 to a team assembled by the University of Vermont (UVM). The work of the UVM technical team is ongoing through May of 2022.

IV. PES Working Group: Fall 2021

With the assistance of the UVM technical team, the Working Group accomplished the following tasks and activities. The final documentation for these tasks and activities can be found on the PES WG webpage: https://agriculture.vermont.gov/pes

A. *Measuring Ecosystem Services from Soil Health*: Building on the WG's spring soil health matrix, the technical team further refined the soil health indicators that could make up or define soil health and identified available methods and costs for measuring these soil health indicators. This information will allow the WG to build a PES program based on specific, meaningful, measurable indicators of soil health. The soil health indicators identified by the WG include:
   - Organic matter
   - Bulk density
   - Aggregate stability
   - Green House Gas emissions and sequestration modeling
   - Biodiversity

   These indicators in turn represent or result in five ecosystem services of interest as identified by the 2019 PES WG, as written into statute as a findings and recommendation goal, and as subsequently refined by the WG include: climate regulation (carbon), downstream flood mitigation, soil conservation and water quality protection, climate resilience and biodiversity.

B. *Establishing a Value for Ecosystem Services resulting from Improved Soil Health*: The PES Working Group utilized the UVM team to develop cost estimates for: 1) a "best" case scenario of a soil organic matter 50% higher than a reference condition and bulk density 20% lower; and 2) a "good" case scenario of a soil organic matter 25% higher than a reference condition and bulk density 10% lower. These soil health improvements would in turn produce ecosystem services for flood mitigation, erosion reduction, phosphorus retention, carbon storage, nitrogen retention, and soil biodiversity. Separately, the UVM team conducted a valuation of these benefits for these scenarios in dollars per acre. This information provides the WG essential valuation information, based on defensible analysis, for incorporating into a PES program and establishing prices and payments.

C. *Summarizing VT Farmer PES Program Proposals*: The WG reviewed a summary prepared by the technical team of three PES program concepts designed by Vermont farmers for Vermont farmers. These "home-grown" ideas will provide valuable options and ideas for designing a PES program(s) by the WG in 2022. While varying in detail, all these programs assume participants are in "good standing" with VAAFM, farmers would be paid a base amount for participating, testing, and engaging, and the program would be tiered where farmers could be paid more for increased performance in providing ecosystem services.

D. *Reviewing Existing PES Programs*: The UVM team also undertook a review of several PES programs already underway in the U.S. and abroad. This report in includes a comparison of 10 programs involving such ecosystem services as soil health, carbon storage, water protection, and nutrient retention. The lessons from these programs will help inform WG as it hones one or more program designs in 2022.

E. *Supporting Integration of Agroforestry Practices in Vermont Conservation Practices.* The WG identified a few key NRCS agroforestry practices that are currently not funded in Vermont. The NRCS-VT Office is now pursuing how to include additional practices eligible for payment in Vermont.

V. PES Working Group: 2022 Areas of Focus

The PES WG is well-positioned to build on its work to discuss, explore, define, and hone and recommend one or more programs for payment of ecosystem services. The Governor's Future of Agriculture Commission and the Vermont Climate Council also support the on-going advancement of a PES program or programs in Vermont. The PES WG anticipates being able to deliver a final report on January 15, 2023 that provides the findings and recommendations outlined in Act 129 of 2020.

2021's focus has been on soil health and the WG will continue to work with the UVM team to design a soil health program. This work will include developing and exploring various program design elements, reaching out to farmers and technical advisors through surveys and focus groups to further test ideas and willingness to accept dollars for outcomes or outputs, and creating a well-analyzed and supported program.

In addition, and importantly, the WG will explore in 2022 PES program possibilities beyond soil health including edge-of-field[1] monitoring, and whole farm approaches that might further advance ecosystem services and farm incomes.

More about the WG and its work can be found at: https://agriculture.vermont.gov/pes.

VI. Appendices

A. PES Working Group Members
B. PES Working Group Meeting Summary Information

[1]According to NRCS, voluntary edge-of-field water quality monitoring enables agricultural producers and scientists to quantify the impacts of conservation work on water quality. Through edge-of-field (EoF) monitoring, NRCS works with producers and conservation partners, such as universities, agencies, and non-governmental organizations, to measure the amount of nutrients and sediment in water runoff from a field and compare the improvements under different conservation systems.

<u>Appendix A: PES Working Group Members</u>

Pursuant to Section 24 of Act 129 of 2020
The Working Group shall include the following members:

1) the Secretary of Agriculture, Food and Markets or designee;
    a) Deputy Secretary Alyson Eastman
2) the Secretary of Natural Resources or designee;
    a) Marli Rupe (DEC)
3) a representative of the Vermont Housing and Conservation Board;
    a) Stacy Cibula
4) a member of the former Dairy Water Collaborative;
    a) Brian Kemp (CVFC)
5) two persons representing farmer's watershed alliances in the State;
    a) Paul Doton (CRWFA)
    b) Scott Magnan; Franklin & Grand Isle Farmer's Watershed Alliance (FWA)
6) a representative of the Natural Resources Conservation Council;
    a) Jill Arace (VACD)
7) a representative of the Gund Institute for Environment of the University of Vermont;
    a) Alissa White
8) a representative of the University of Vermont (UVM) Extension;
    a) Joshua Faulkner
9) two members of the Agricultural Water Quality Partnership;
    a) Matt Vaughan (LCBP)
    b) Vicky Drew (NRCS-VT)
10) a representative of small-scale, diversified farming;
    a) Maddie Kempner (NOFA-VT)
11) a member of the Vermont Healthy Soils Coalition
    a) Cat Buxton / Didi Pershouse
12) a person engaged in farming other than dairy farming;
    a) Ed Pitcavage (Philo Ridge Farm)
13) a representative of an environmental organization with a statewide membership that has technical expertise or fundraising experience;
    a) Heather Furman, The Nature Conservancy in Vermont
14) an agricultural economist from a university or other relevant organization within the State;
    a) David Conner, University of Vermont [*now vacant*]
15) an ecosystem services specialist from UVM Extension; and
    a) Juan Alvez
16) a soil scientist
    a) Meredith Albers (NRCS-VT)

Appendix B: PES Working Group Meeting Summary Information

2021

Tuesday, March 16th, 2021 from 1:00-3:15pm, via Zoom.
3/16/2021 Agenda & Call-in Information | 3/16/2021 Meeting Recording
Supporting Materials:
CBI Agenda & Background
Jon Winsten: Soil Health Investment Trust
Bio Logical Capital, Vermont Land Trust & UVM Extension: CIG Soil Health Research
Ryan Patch, AAFM: Current AAFM PES Projects
Jennifer Byrne: VT Soil Health Policy Network

Thursday, April 15th, 2021 from 1:00-3:00 PM, via Zoom.
4/15/2021 Agenda & Registration Information | 4/15/2021 Meeting Notes
Supporting Materials:
Work Approach
Related Research

Wednesday, April 28th, 2021 from 12:30-2:00PM, via Zoom.
4/28/2021 Agenda & Registration Information | 4/28/2021 Meeting Notes
Supporting Materials:
Task Group Workplans

Wednesday, May 12, 2021 from 12:30-2:00PM, via Zoom.
5/12/2021 Agenda & Registration Information | 5/12/2021 Meeting Notes

Wednesday, May 26, 2021 from 12:30-2:00PM, via Zoom.
5/26/2021 Agenda & Registration Information
Supporting Materials:
Task Group Update

Wednesday, June 9, 2021 from 12:30-2:00PM, via Zoom.
6/9/2021 Agenda & Registration Information
Supporting Materials:
Draft Mitigation Strategies Template
Economics Soil Health Value Matrix
Soil Health Task Group Draft Approach
Input on PES: Stephen Leslie

Wednesday, June 22, 2021 from 12:30-2:00PM, via Zoom.
6/22/2021 Agenda & Registration Information
Supporting Materials:
Soil Health Values Matrix
Progress Summary

Tuesday September 21, 2021 from 12:00 - 2:00PM, via Zoom
9/21/2021 Agenda & Registration Information
9/21/2021 Meeting Recording
Supporting Materials:
The State of Soil Health in VT Project Update

Tuesday October 5, 2021 from 12:00 - 2:00PM, via Zoom
10/05/2021 Agenda & Registration Information
10/05/2021 Meeting Recording
Supporting Materials:
PES Research Contract Overview
Presentation: Responsible Innovation and Precision Ag

Tuesday October 19, 2021 from 12:00 - 2:00PM, via Zoom
10/19/2021 Agenda & Registration Information | Meeting Recording | Summary
Supporting Materials:
CSP+ Proposal for Discussion
Past CSP+ Webinar for Review
CSP+ Slides
Enhanced TA Teams Proposal Slides
Program Design Slides

Tuesday November 2, 2021 - *MEETING CANCELLED*
11/2/2021 Agenda & Registration Information

Tuesday November 16, 2021 from 12:00 - 2:00PM, via Zoom
11/16/2021 Agenda & Registration Information | Meeting Recording
Supporting Materials:
Review of PES Legislative Language
UVM Research Team Update Presentation
Ag & Soil Health Co-benefits - Ryan Patch
Soil Health and Biodiversity - Becky Maden

Tuesday December 07, 2021 from 12:00 - 2:00PM, via Zoom
12/07/2021 Agenda & Registration Information | Meeting Recording | Summary
Supporting Materials
PES Program Tables
UVM Updates
Stephen Leslie - Small Farmer Input
PES Observed Metrics

Tuesday December 21, 2021 from 12:00 - 2:00PM, via Zoom
12/21/2021 Agenda & Registration Information | Meeting recording | Summary
Winsten Program Design slides
UVM Soil Health Valuation slides

Draft ES Valuation Report (UVM)
Draft Farmer PES Concepts Report (UVM)
Draft Measuring Soil Health Report (UVM)
Draft Review of PES Program Report (UVM)

VERMONT PAYMENT FOR ECOSYSTEM SERVICES & SOIL HEALTH WORKING GROUP PROGRAM OBJECTIVES, ELEMENTS, AND ASSUMPTIONS

Vision:

A Payment for Ecosystem Services and Soil Health Program will promote climate resilience and mitigation, provide clean water, and improve the health of the broader ecosystem for all Vermonters, while also supporting the economic health of Vermonters engaged in agriculture.

Goals:

The Payment for Ecosystem Services and Soil Health Program will:

- Compensate farmers for providing clearly defined ecosystem services.[1]
- Ensure that metrics and associated compensation are clearly and directly linked to the specific, quantifiable ecosystems services of carbon storage, nutrient, soil retention, stormwater retention, and ability to support biodiversity.
- Identify and pay for ecosystem services that could be provided by farms of diverse types and sizes, including those currently and historically underserved by payment programs.
- Be efficient with time and funding to ensure that a high return is provided to the farmer and society.
- Continually improve both research and the program to support agricultural innovation, adaptative management and development of new practices and tools.

Framework:

Eligibility

1. All farmers are eligible to participate in the program if they are in good standing with the Required Agricultural Practices (RAPs). However, only those farmers who meet the standards set forth by the program will receive payments. [2]
2. Participation in the program will be completely voluntary.

[1] The Working Group's 2020 Report to the Legislature defines ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" i.e. "the set of ecosystem functions that are useful to humans."
[2] Definitions and determinations for farms under the RAPs are outlined here.

3. The program will strive to ensure that historically underserved producers, as defined by USDA, are encouraged to participate and provided with technical assistance to do so.[3]
4. Farmers will be compensated, at least in the initial year(s), for the additional workload required, including data gathering and associated paperwork, soil sampling, and time spent supporting program development and implementation.

Program Phasing

1. The program will be developed in phases to: 1) allow for initial implementation; and 2) to allow for the ability to grow in the services it pays for over time.
2. The program will start as a one-year pilot/demonstration at the scale allowed by funding in order to: 1) move action forward; 2) learn from initial implementation; and 3) provide compensation to farmers for producing ecosystem services.
3. The pilot will seek to enroll a manageable number of farms to ensure that those farms can meaningfully benefit given overall funds appropriated.
4. The pilot will seek to be representative of the outcomes the program seeks to achieve and the diversity of farms it intends to reach.
5. The pilot program will focus on outcomes in the soil (e.g., improved carbon sequestration), in the field (e.g., more diverse cover crops to support biodiversity), and at edge of field (e.g., increased stormwater retention) while considering outcomes in other parts of the farm.
6. The Working Group will stay engaged throughout the rollout and initial implementation of the pilot program to support, monitor, and provide guidance, at least through the group's statutory deadline of early 2023.
7. The Vermont Agency of Agriculture, Food & Markets will administer the pilot program given its areas of authority, expertise, staff capacity, and ability to begin implementing the program in late 2022. However, the ultimate program administrator may be a different entity.[4]

Program Elements

1. The program will pay for ecosystem services based on outcomes, which may be determined via real-time measurements, modeling, or a combination.
2. The program will be organized into tiers, which may include different payment levels for: 1) enrollment and basic data collection and soil testing; 2) incorporating evidence-based practices that have been demonstrated to produce ecosystem service outcomes; 3) measured outcomes in soil health and other metrics, with more extensive monitoring and sampling; 4) advanced research and/or innovation.[5]

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[3] USDA definitions for historically underserved producers are outlined here.
[4] Note that there would need to be considerations for data privacy, which would be based on the funder's requirements rather than the administrator's.
[5] The California Healthy Soils Program provides funding for "demonstration projects" that research and demonstrate innovative management practices. More information on HSP demonstration projects is available here.

3. The program will incorporate a research element to: 1) monitor and provide analysis for program development and adaptive management; and 2) support innovation and development of new practices and tools over time.
4. The program will track results and make improvements to the program on a periodic basis.
5. The program will compensate for outcomes that exceed stated thresholds that are higher than requirements under the RAPs, as well as improvements over baseline conditions. These parameters will be further determined during program design.
6. The program will integrate farmer learning networks and other collaborative tools for co-production of benefits and improvements to the program overall over time.
7. To the greatest extent possible, the program will seek to incorporate data interoperability with current programs to streamline existing data for efficiency and ease of use.
8. The program will coordinate with, be additive to, and be compatible with existing funding programs to the greatest extent possible.
9. The program will support farming practices that promote and protect biodiversity while keeping farmland in production.
10. The program will: 1) seek outcomes on some or all parts of the participating farms to allow entry, adaptation, and adaptation; and 2) strive to avoid or minimize "leakage" from enrolling only the best-managed fields, while others remain at low management levels. Options include: 1) enrolling a representative sample of fields from a farm; and 2) requiring that enrolled farms submit a map of all acreage for future consideration.
11. The program will ensure that 1) ecosystem services are valued through payments such that farmers' benefit from enrolling exceeds their marginal cost; and 2) adequate technical assistance is provided to assist farmers with enrollment.
12. The pilot will identify ways to deploy technical assistance effectively and efficiently, and where possible involve existing support entities, such as conservation districts, University of Vermont Extension, farmer watershed groups, and independent providers.
13. The long-term program design will consider whether payments are permanent and annual or intended to phase out over time once behavioral changes become normalized.

Program Tools

1. A Vermont-tailored Cornell Comprehensive Assessment of Soil Health (CASH) test will be developed for the program. For the pilot, a standard or modified CASH test will be used as the Vermont-tailored version is developed.
2. Exact models to be used are to be determined but may include USDA-NRCS' Resource Stewardship Evaluation Tool (RSET), USDA's Agricultural Policy/Environmental eXtender model (APEX), others, or some combination. The program will also incorporate farmer-led tools (like observation and in-field tests) wherever possible.
3. The program should rely on tools that are 1) applicable to conditions in Vermont; 2) cost-effective; 3) easy-to-use; 4) able to and provide clear, measurable and direct connections to soil health and the ecosystem services identified.

Payments

1. Payments will be based on evidence-derived values that consider both society's willingness to pay (WTP) and farmer's willingness to accept (WTA).
2. Payments may be paid in a tiered, threshold manner for: 1) having a score that is equal to or greater than a stated threshold (given field, soil type, cropping type, and other conditions) to reward good practice and those already producing valued ecosystem benefits; and 2) measured improvements from their farm's baseline (given field, soil type, cropping type, and other conditions) to reward improvement. Program design will outline parameters and levels for thresholds and improvements.
3. The program and the pilot will seek to maximize funding from a variety of sources to the extent possible (state, federal/NRCS, and other sources).

Farmer Engagement

1. The program will partner with existing agencies and initiatives across the state to increase public understanding and appreciation of the role of agriculture in healthy landscapes and the importance of ecosystem services for a healthy environment and quality of life.

Pilot Development Process

1. The Working Group will develop program parameters and elements by 15 June 2022, based on discussions among the Working Group and research, case studies, and recommendations from the UVM technical services team.
2. AAFM staff and a subgroup of Working Group members will work from June-August 2022 to design the pilot program based on the Working Group's parameters and research completed under the UVM technical services contract.
3. Working Group members and interested members of the public will be kept informed via bi-weekly email updates from the program design team and will be provided opportunities for input and comment, with one week for comment when possible.
4. The Working Group will begin to engage farmers and members of the public around the program parameters and elements during the summer and into fall 2022. This document will be posted on the AAFM website. Working Group members will be encouraged to share the document within their networks including to groups such as farmer watershed groups, Vermont Healthy Soils Coalition, UVM Extension, Vermont Agriculture Water Quality Partnership, the Vermont Climate Council, the Governor's Commission on the Future of Vermont Agriculture, and others. AAFM and the Working Group may create a short set of talking points to support outreach.
5. The design team will report back to the Working Group in September 2022.
6. The Working Group will refine and hone final issues and questions with the design team during fall 2022.
7. The pilot program will then be finalized in late 2022, after which implementation will begin.

Draft Approach 6: USDA-NRCS Conservation Stewardship Program (CSP) With a Vermont State Enhancement (VSE)

This approach to evaluating, quantifying, and paying on ecosystem services provided by an agricultural operation leverages the UDSA NRCS Conservation Stewardship Program's (CSP) assessment and payment framework. This approach would support farms to enroll their whole farm into the CSP program and have their cropland, pastureland, production area, and associated agricultural land be assessed against performance-based stewardship thresholds. State supplemental payments under this approach would initially support farms in their first year of engagement with the CSP program through the 'resource assessment' phase, which is a valuable exercise for farms and promotes comprehensive stewardship planning on the farm. Additional state supplemental funds would then compensate farmers for committing to increased stewardship upon execution of the CSP agreement. Finally, additional supplemental payments will be released by the state annually for successful implementation of the CSP plan, which will support engagement in the program over the five years of the agreement.

Pros:

- Observed in-field and edge-of-field conditions inform field-specific assessment against national thresholds.
- Based on observations that are related to the intended outcomes – "you can see the results".
- Leverages existing work (NRCS resource assessments and conservation planning) and supports farmer access to funds through existing programs – doesn't "reinvent the wheel".
- Could have a long-term impact on the CSP program by mitigating main barriers to the program (lack of farmer & staff familiarity with the program), thereby supporting overall state conservation goals.
- CSP supports high-achieving producers yet requires additionality: enrolled producers must install enhancements to improve existing practices.

Cons:

- High assessment need - significant staffing costs for in-field assessment and observation. Requires trained staff to evaluate to national QA/QC standards.
- Performance standard is observation-driven rather than measurement-driven, outcomes are not measured

Possible Program Details/Considerations:

Ecosystem Service Valued: Soil Management, Water Management; Aquatic & Terrestrial Habitat, Pesticide Management

Output: Performance – in-field and edge-of-field observations and farmer planned management are evaluated against national thresholds by NRCS-certified Conservation Planners.

Quantification: In-field and edge-of-field observations are conducted and recorded. Results are entered into the NRCS user interface, which evaluates all observed data. Evaluations include following resource concerns:

a. Wind and Water Erosion
b. Concentrated Erosion
c. Soil Quality Limitation
d. Field Sediment, Nutrient, and Pathogen Loss
e. Field Pesticide Loss
f. Aquatic Habitat
g. Storage and Handling of Pollutants
h. Degraded Plant Condition
i. Pest Pressure
j. Fire Management
k. Livestock Production Limitation
l. Terrestrial Habitat
m. Source Water Depletion
n. Inefficient Energy Use

'Whole Farm' Consideration:

a. This program takes a whole farm approach. This program targets state supplemental payments to jurisdictional RAP farms that manage cropland and/or pasture, but forestland, production areas, and associated agricultural land on those farms are also evaluated and compensated through CSP.

Modeling costs:

a. CSP is administered by USDA NRCS and uses existing models in an existing workflow.

Who Pays?

a. Payment is provided annually to farmers with CSP contracts by **NRCS** for:
    a. Stewardship Threshold Payments – $300 payment per resource concern (see list above) stewardship threshold met per land use
    b. Land Use Payments – $0.50-$7.50 per acre payment per land use for all eligible farm acreage
    c. Enhancement Payments – payment for ~100% the cost of improving existing conservation practices

b. Supplemental payment is provided to farmers by the **State** for:
    a. <u>Planning Completion Payment (PCP)</u> – paid upon completion of resource assessment and plan, prior to CSP contract – $2,000 / farm
    b. <u>Contract Incentive Payment (CIP)</u> – paid upon development and execution of CSP contract which contains cropland and/or pasture – $1,500 / farm
    c. <u>Practice Incentive Payment (PIP)</u> – Grant incentive for successful enrollment in a agricultural CSP contract signed with USDA NRCS-VT – variable rate / farm (See budget details).

Who Verifies?

a. Certified or trained Conservation Planner staff conduct the evaluation/verification of baseline conditions and of practice implementation.

How often Evaluate?

a. Evaluation and resource concern assessment occurs prior to CSP contract execution.
b. Verification occurs annually thereafter, in existing NRCS workflow

Payment

a. <u>New enrollees</u>: New enrollees are eligible for all of the different supplemental payment types in sequence. At the rates estimated above, over the course of a 5-year CSP contract, a new enrollee would receive between an estimated $4,500 - $9,000 per farm in supplemental financial assistance payments from the state, and between $6,000.00 and $200,000.00 from NRCS.
b. <u>Existing enrollees</u>: Existing Ag-CSP enrollees are eligible for both PCP and CIP payments for the remainder of their CSP contract. Existing Ag-CSP enrollees would receive a $3,500 one-time payment.
c. <u>Note</u>: a farm might develop a plan and undergo the resource concern evaluation but not end up signing a CSP contract. If so, that farm would just receive the Planning Completion Payment of $2,000.00.

Baseline

a. Not a baseline approach – but does need to demonstrate "enhancement" from management at time of assessment of resource concerns.

Threshold

a. Stewardship Thresholds are established by NRCS. All land managed by a farm are assessed through CSP to each respective land uses' standards in each resource concern category. A minimum of two resource concerns must be met on each land use area.
b. Farms will need to meet the Stewardship Thresholds for Cropland and/or Pasture and install enhancements on at least one of these land use types to be eligible for the Contract Signing Payment or Annual Implementation Payments.

Farm Eligibility

a. Farms must be eligible for USDA Farm Bill programs
b. Farm must meet the jurisdictional RAP farm definition
c. Farms must meet or plan to the CSP stewardship thresholds for the cropland and/or pasture that they manage.
    a. This includes those already enrolled in the CSP program – they are eligible for Annual Payments on the years remaining in their CSP contract.
d. Farm must be in good standing with VAAFM.

Farm Ranking

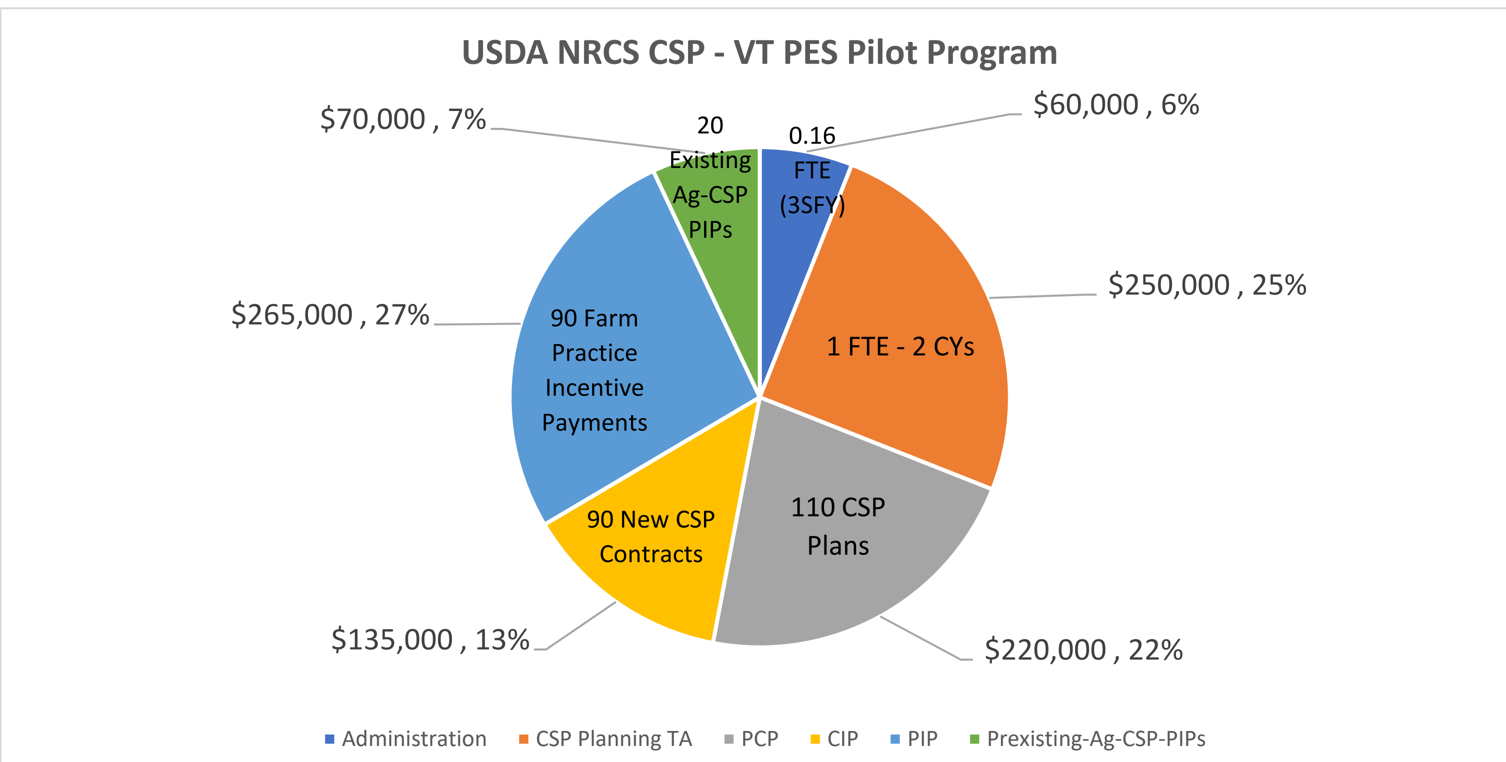
a. First come first served based on application deadlines set by program.

Pilot Specifics

a. Two years of funds made available to support one- to six-year contracts for qualifying farms (to match CSP contract timelines) who work to sign up for CSP in Calendar Year 2023.

Payment Scenarios:

One payment scenario has been considered for this pilot thought experiment. These payment rates are based on data reported in the PES WG Task 5: Valuation of Ecosystem Services report. A fixed cost of 6% is considered for administration costs between program payment rates – this will need to be revisited as complexity is introduced into a program and cost to administer is fully considered. Additional funds are set aside to support conservation planning and peer-to-peer farmer outreach over two calendar years. The remaining 69% of funds would go out to farmers as funds for conservation plans, CSP contract signature, and annual payments for continuing to work towards performance outcomes over the course of the program.



Appendix G

Definitions

Administration: Contract, grant, and payment processing activities.

Technical Assistance: technical assistance is a service assisting landowners and agricultural producers in conserving natural resources and provides the planning, design, and technical consultation functions.

Financial Assistance: offers monetary support for implementation capacity in the form of grants.

Planning Completion Payment (PCP): One time grant award for a farmer successfully completing the conservation planning steps necessary to be ranked for the USDA NRCS CSP Program.

Contract Inventive Payment (CIP): One time grant award for a farmer successfully executing and signing a contract with USDA NRCS-VT for an agricultural CSP agreement and an incentive payment to ensure implementaiton of plan over the five-year duration of the contract.

Practice Incentive Payment (PIP): Grant incentive for successful enrollment in a agricultural CSP contract signed with USDA NRCS-VT.

PES-WG CSP Payment Scenario Calculator

State Fiscal Year (SFY)	SFY23	SFY 24	SFY 25	Total
Administration				
Administration	$ 20,000	$ 20,000	$ 20,000	**$ 60,000**
Other				
Technical Assistance				
CSP Planning TA	$ 62,500	$ 125,000	$ 62,500	**$ 250,000**
Other				
Other				
Financial Assistance	Anticipated Payments / Year*			Total
PCP	30	50	30	110
CIP	20	30	40	90
PIP	20	30	40	90
Prexisting-Ag-CSP-PIPs	20	-	-	20
	20			

IIP Annual Payments

			% Budget
Avaliable Funding:		**$ 1,000,000**	*100%*
Administration			
Admin		$ 60,000	
		$ -	
Subtotal		$ 60,000	*6%*
Avaliable Funding Less Admin:		**$ 940,000**	
Technical Assistance			
TA		$ 250,000	
-		$ -	
-		$ -	
Subtotal		$ 250,000	*25%*
Avaliable Funding Less Admin & TA:		**$ 690,000.00**	
Annual Payment Rate			
	$ 2,000	$ 220,000	
	$ 1,500	$ 135,000	
	$ 2,944	$ 265,000	
	$ 3,500	$ 70,000	
Subtotal		$ 690,000	*69%*
Planned Total:		$ 1,000,000	

PCP + SIP + PPIP	Avaliable for PIP
$ 425,000.00	$ 265,000.00

Appendix H

	Pilot Approach	1 - Soil Testing (CASH)	2 - Soil Testing (Soil Carbon)	3 - Soil Carbon Modeling	4 - Observation & Modeling	5 - Observation	6 - Bridge to CSP
Program Details	Ecosystem Service	Soil Health	Soil Carbon Accumulation	Soil Carbon Accumulation	Soil, Water, Pesticide, Air & Habitat	?? Soil, Water, Pesticide, Air & Habitat ??	Soil, Water, Habitat & Pesticide
	Measured or Modelled?	Measured	Measured	Modelled	Observed & Modelled	Observed	Observed & Modelled
	What is Quantified?	Score (e.g. "Excellent")	Change in Soil Carbon (tons CO2e)	Carbon sequestered (tons CO2e)	Score (e.g. "Excellent")	Score (e.g. "Excellent")	Avoidance of Resource Concerns
	Quantification Tool	CASH Test	Standard soil test, bulk density	APEX (NRCS model)	RSET (NRCS model)	NRCS Score Sheets	CART Planner (NRCS model)
	Payment rate (Willingness to Pay)	$20.68-$29.89 per acre	$51 per ton CO2 equivalent	$51 per ton CO2 equivalent	$20.68-$29.89 per acre	$20.68-$29.89 per acre	$9,000 per producer for 5 years
	Whole Farm?	Not necessarily	Not necessarily	Yes	Yes	Yes	Yes
	Threshold or Baseline?	Threshold	Baseline	Baseline	Threshold	Threshold	Threshold
	Threshold/Baseline Info	Tiered - Good & Excellent	Year 1 results = baseline	Year 0 results = baseline	Tiered - Good & Excellent	Tiered - Good & Excellent	Flat - Avoidance of at least 2 resource concerns per land use type
	Coordinate with:	NRCS Soil Testing/Soil Health Plan	Existing farm soil tests	Vermont Pay for Performance	N/A	N/A	NRCS Conservation Stewardship Program
	Other considerations		3-5 year delay until payment Bulk density tests difficult	model calibration funded elsewhere. Lots of computer time	Would need extensive training of observers	Would need extensive training of observers. Would need to define threshold(s) & calibrate with Vermont	
Roles/ experiences/ benefits	Farmer	Year 1: Take CASH tests, receive payments if above threshold Eligible again in 3 years.	Year 1: take soil organic matter & bulk density tests Year 3: take tests again Year 3: receive payment for increase in carbon stock	Year 1: install practices, provide management data to TA provider. Receive payment for carbon modelled as sequestered that year. Eligible again in 1 year	Year 1: install practices, provide management data to TA provider. Receive payment if above threshold. Eligible again in 1 year	Year 1: install practices. Receive payment if above threshold. Eligible again in 1 year	Year 1: Plan, Receive Payment. Apply to CSP. Sign CSP contract, receive payment. Years 2-6: Maintain stewardship, install practice enhancements, receive payment.
	TA provider	Take CASH tests Interpret CASH tests Recommend practice changes that may increase CASH score	Take bulk density tests Recommend practice changes that may increase organic matter	Enter management data in model. Verify installation of practices Recommend practice changes that will increase carbon sequestration.	Enter management data in model. Verify installation of practices. Perform in-field observations. Recommend practice changes that will increase RSET score.	Perform in-field observations. Recommend practice changes that will increase threshold score.	Become trained in NRCS conservation planning. Assist farmer with planning & resource assessment. Assist NRCS with annual verification thereafter.
	Program manager	Reimbursement for CASH test TA and lab fees. Payments to farmers with high CASH tests	Reimbursement for bulk density test TA and lab fees. Payments to farmers for increases in carbon stocks	Reimbursement to TA providers and farmers for time entering data. Payments to farmers for carbon sequestion.	Reimbursement to TA providers for time entering data and performing observations. Payment to farmers with high RSET scores.	Reimbursement to TA providers for time performing observations. Payment to farmers with high scoresheet scores.	Reimbursement to TA providers for time getting trained and performing outreach, planning and resource assessment. Payment to farmers for deliverables associated with planning, contract, and annual verification.
	Benefit to public/State	Demonstrably high soil health is linked to climate & water regulation. No link to state climate or water quality accounting.	Carbon sequestration benefits the public & Vermont's climate action plan. Difficult to link to state climate accounting. No link to water quality accounting.	Carbon sequestration benefits the public & Vermont's climate action plan. Can be linked to state climate and water quality accounting via practices.	Effective Soil, Water, Air, Pesticide & Habitat management benefits the public. Can be linked to state climate and water quality accounting via practices.	Effective Soil, Water, Air, Pesticide & Habitat management benefits the public. No link to state climate or water quality accounting.	Effective Soil, Water, Habitat & Pesticide management benefits the public. Can be linked to state climate and water quality accounting via practices. Driving enrollment in CSP also supports NRCS to access more federal funds for PES.
PES & SH Working Group Goals	Ecosystem Services clearly defined	In a way	Yes	Yes	Yes	No	
	Ecosystem Services clearly quantified	In a way	Yes	Yes	In a way	In a way	In a way
	Compensation directly linked to Ecosystem services	In a way	Yes	Yes	In a way	No	In a way
	Compensates for carbon storage	In a way	Yes	Yes	In a way	In a way	In a way
	Compensates for nutrient and soil retention	In a way	No	No	In a way	In a way	In a way
	Compensates for stormwater retention	In a way	No	No	In a way	In a way	In a way
	Compensates for ability to support biodiversity	No	No	No	In a way	In a way	In a way
	Can compensate farms of diverse types	Yes	Yes	In a way	In a way	Yes	Yes
	Can compensate farms of diverse sizes	Yes	Yes	Yes	Yes	Yes	Yes
	Time-efficient (low TA need)	Yes	No	No	No	In a way	Yes
	Funding-efficient (high % of funds to farmers)	In a way	No	In a way	No	In a way	Yes
	Opportunity to support future research	Yes	Yes	Yes	In a way	In a way	In a way
	Opportunity to support future program changes	Yes	Yes	Yes	Yes	Yes	Yes
Farmer Survey Goals	Meets farmer willingness to accept ($50-100/ac)	No	No	No	No	No	In a way
	Easy for farms to access	Yes	Yes	In a way	In a way	Yes	Yes
	Coordinates with existing programs	In a way	In a way	Yes	No	No	Yes
	Additionality (pays for improvements)	No	Yes	Yes	No	No	No
Meets Goals	*Overall score (Yes is 1, In a way is 0.5, No is 0): GOALS not weighted in any way*	*0.588235294*	*0.617647059*	*0.617647059*	*0.382352941*	*0.470588235*	*0.647058824*

Appendix I

Baseline payment is for year 1 enrollement; payments each year thereafter are for progress in each category.
Farmer choses weight of importance of each metric.

Instructions: circle the box ranging from 1 (low/ no achievement) to 4 (high achievement) on the spectrum below for each biodiversity outcome indicator.

Low/no achievement --> High achievement

Indicator/ High Achievement	1	2	3	4	How measured?	If achievement level is 1-2, write steps to improve here	Weight of importance of each indicator to farmer (1=low, 4= high)	Score (weight x achievement)	Suggested resources/ examples
1. Whole Farm									
Conservation and Wildlife	No documented/mapped conservation areas, practices, or plans.			**Conservation areas, practices, and plans appear on the farm map.**	Maps/ photos, documented progress from year to year.				*fill this column with resources helpful for farmer*
	No natural or semi-natural areas identified on the farm.			**Farm property has some natural areas (woodlands, wetlands, grasslands) and semi-natural areas (hedgerows, alley plantings).**	Maps/ photos, documented progress from year to year.				
	Farmer unaware of rare-threatened-endangered species' presence.			**Rare-threatened-endangered species are present and are recognized and protected by land owner.**	Maps/ photos, documented progress from year to year.				
	High presence of invasive plants; no management strategy			**Minimal presence of invasive plants ; native plant community is present**	Maps/ photos, documented progress from year to year.				
	Fragmented wild areas; no connectivity to natural areas outside of farm.			**Connectivity between habitat patches on the farm as well as links to other natural areas.**	Maps/ photos, documented progress from year to year.				
	No observed wildlife, birds, pollinators, etc.			**General abundance of wildlife species observed, such as pollinators, beneficial insects, amphibians, reptiles, birds, and mammals.**	**Note: develop more specific counts/ observational tools here---> Counts, photos, TA guidance**				
Edge of field	No habitat adjacent to fields.			**Diversity and abundance of adjacent**	Maps/ photos, documented progress from				
	No brush or decomposing material around fields.			**Brush piles, decomposing logs, patches of bare soil (for ground-dwelling insects, especially bees) and healthy duff layer in adjacent non-crop habitat.**	Maps/ photos, documented progress from year to year.				
	Invasive plants abundant at edge of fields.			**Native plants dominant in non-crop habitat with sparse invasive non-native plants.**	Maps/ photos, documented progress from year to year.				
	No noticiable wildlife or insects at field edge.			**Diversity of beneficial organisms such as predatory insects, wasp parasitoids, spiders and other arthropods, bats, birds and mammals.**	Maps/ photos, documented progress from year to year.				
2. For Annual Cropping Systems (field crops & vegetables)									
a. In field									
Species diversity	No flowering crops or plants in field.			**Flowering crop and non-crop plants are present.**	Maps/ photos, documented progress from year to year.				
	Minimal soil life.			**Diversity of abundant soil life.**	**Measureable with ecoplates or other soil health tool?**				
	No observed pollinators, beneficials, or birds in field.			**Beneficial insects and birds in field.**	Maps/ photos, documented progress from year to year.				
3. Perennial cropping systems (pastures and hayfields):									
a. In field									
Crop and species diversity	In field monoculture.			**Contains diverse mix of plants.**	Maps/ photos, documented progress from year to year.				
	Minimial biomass and soil cover.			**Healthy biomass and height and cover.**	Maps/ photos, progress from year to year. Meaure and document at same time of year annually.				
	Poor color and growth on plants.			**Good color of plants; large size of plant roots.**	Maps/ photos, progress from year to year. Meaure roots and document at same time of year annually.				
Rotational grazing	No rotational grazing system			**Well-designed and executed rotational grazing system allows forages to recover between grazing episodes.**	Maps/ photos, documented progress from year to year.				
Native plant management	No or few native plants; abundance of invasive plants.			**Includes native plant species and have few or no invasive plant species.**	Maps/ photos, documented progress from year to year.				
Wildlife	Migratory paths for wildlife disrupted by farm operation.			**Migratory paths of wildlife are unimpeded by operation.**	Maps/ photos.				
	No shade in pasture.			**Native trees and shrubs are used for shade.**	Maps/ photos, documented progress from year to year.				[illegible]
				Total score					

The University of Vermont

Measuring ecosystem services from soil health

Vermont Payment for Ecosystem Services Technical Research Report #1

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

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Gund Institute for Environment

THE UNIVERSITY OF VERMONT EXTENSION

EXECUTIVE SUMMARY

Vermont's Act 83 of 2019 identified the need for a payment for ecosystem services (PES) program that would compensate Vermont farmers for providing ecosystem services from agricultural lands, and tasked the Vermont Soil Health and Payment for Ecosystem Services Working Group with making recommendations for the implementation of PES in Vermont. Early on, this effort specifically identified that improved soil health would lead to enhancements in crop resilience, carbon storage, stormwater storage capacity, and reduced agricultural runoff to waters. The ecosystem services the PES working group aspires to incentivize now includes climate regulation (carbon storage and carbon sequestration), downstream flood risk mitigation, climate resilience, water quality, soil conservation and biodiversity.

There are a multitude of approaches to evaluating soil health and the soil processes influenced by soil health. As the state of Vermont explores innovative programs that compensate farmers for soil health and associated ecosystem services, the selection of soil health indicators and quantification methods is a foundational first step that influences other aspects of program design. What is measured determines the ecosystem services that can be inferred, the accuracy of data that informs decisions, and programmatic transaction costs. Simply put, what is measured matters. The PES Working Group identified organic matter, bulk density, aggregate stability, greenhouse gas flux from the soil surface and soil biodiversity as the soil health indicators that would be most closely related to the desired ecosystem services, and contracted with UVM to provide more information on the measurement considerations for these indicators.

In this report, the available methods and costs of measurement for these soil health indicators are discussed in detail. In addition, modeling options are identified. Finally an index that could combine multiple soil health indicators is explored as an option. Overall, this foundational research identified the need for the PES program to integrate both soil health measurements with modeling to validate soil health. Costs for laboratory analysis and labor for these selected metrics were approximately $250 per field, and we identified three analytical laboratories that could provide the soil health analysis.

The contents of this report are intended to support decision-making on the part of the Vermont Soil Health and Payment for Ecosystem Services Working Group about what will be measured in a PES, but do not constrain the group from adding other metrics should they so desire. This decision must balance accuracy and complexity with the cost of measuring the best indicators of performance. These decisions are foundational to other aspects of PES program design.

KEY MESSAGES:

- Soil health indicators selected by a VT PES Working Group Subcommittee can be used as indicators of five ecosystem services of interest: climate regulation, downstream flood risk mitigation, soil conservation, climate resilience and biodiversity. These soil health indicators are organic matter, bulk density, aggregate stability, greenhouse gas flux from the soil surface and soil biodiversity. Based on our research, four of the five metrics are feasibly measurable for a PES: aggregate stability, organic matter, bulk density and biological diversity.
- Soil health is not a strong enough indicator of water quality to be included in a soil health PES.
- Measuring and monitoring soil carbon is achievable. It requires multi-year monitoring of soil carbon, and training in the collection of bulk density measures.
- Measuring and monitoring of greenhouse gas flux from the soil surface is cost prohibitive and time intensive. Weakly to moderately accurate models for greenhouse gas flux exist but may not capture all management practices for Vermont.
- Measuring and monitoring indicators of downstream flood risk mitigation is achievable, but field location and connectivity to waterways determine the provisioning of downstream flood risk mitigation and should be incorporated into program design thoughtfully.
- Soil biodiversity can be measured through changes in soil microbial diversity and/or monitoring of soil invertebrate populations.
- Inherent field location and soil texture influence the provisioning of ecosystem services, and the working group should carefully consider whether payments consider those static characteristics.
- The metrics researched here can be evaluated at the field scale, but some ecosystem services, such as climate mitigation services in particular, could be assessed at the net whole farm scale.
- Using consistent procedures and labs will be important for comparing data over time and between locations. Comparative benchmarking data would be helpful to determine additionality over time at a farm scale, or additionality in comparison to expected optimal ranges and thresholds.
- Measurement costs for this suite of indicators will be approximately $200 to $300 per field. Estimated costs for lab analysis of the selected soil health indicators per field comes to a range of **$68 - $142**, this does not include labor for sample collection or shipping costs to labs for analysis.
    - Organic matter: **$4-8**
    - Bulk density: **$24-$30** (3 subsamples at $8-10 each)
    - Aggregate stability: **$10-24**
    - GHG modeling: $0
    - Biodiversity: **$30-80**
- A soil health index based on these metrics could make determination of payment rates easier. If an index was to be pursued, a facilitated process for determining appropriate weighting and incorporation of site and soil characteristics would need to take place.

INTRODUCTION

During the spring/summer of 2021 a subcommittee of seven Vermont PES Working Group members met to determine a set of soil health measurements that could be used as indicators of ecosystem services for a Vermont PES program. The subcommittee included scientists, state agency staff and a farmer. The group explored lengthy lists of soil health measurements and then discussed further those that indicate the ecosystem services of interest for PES in Vermont. The group also considered challenges such as labor and cost and sought to minimize the number of measurements. The group was able to develop a concise list of five measurements that could be used to indicate five ecosystem services of interest (Table 1). This list was passed along to our team to refine, build out considerations for measurement, modeling and to explore the concept of an index that combines the measurements.

The goal of this paper is to provide background research that will support Vermont PES Working Group members in further refining their list of soil health indicators.

Soil health measurements as indicators of ecosystem services

There is no single measure of soil health. The USDA NRCS defines soil health as the “continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.”[1] This definition highlights the dynamic, living and interconnected nature of soil health as a concept. Many biological, physical and chemical characteristics of soil related to ecological function are measured as indicators of soil health. Some laboratories offer suites of tests as soil health testing packages that capture multiple aspects of soil health. The soil health indicators selected for a PES program in Vermont should express the social benefit and ecological function behind the ecosystem services of interest, while balancing any practical challenges and costs that might be associated with each measurement.[2]

The Vermont PES Soil Health Working Group has identified climate regulation, downstream flood risk mitigation, biodiversity, and water quality as critical ecosystem services for Vermont. Measurable characteristics of soils have well established links to some of these ecosystem services, however, the link between water quality and soil health can be tenuous[3,4] . Many water quality conservation practices have soil health co-benefits, but because there is not a consistent causal link from soil health to water quality, and in light of the potential for trade-offs in this regard, a recommendation was made to instead rely on several well-developed tools for assessing water quality outcomes (i.e., VT P-index, APEX). Hence, the working group removed water quality from the list of ecosystem services related to soil health metrics (Table 1).

The selected soil health metrics are dynamic soil properties, which are both measurable and indicative of changes in ecosystem services (Tables 1 and 2). The list of selected indicators is not comprehensive— rather, it is intentionally concise. The subcommittee sought to limit the cost and complexity of soil health measurement, and decided to eliminate indicators that were either redundant or not directly indicative of the ecosystem services. The result is a list of five metrics, and some of the selected soil health indicators can be used to inform multiple ecosystem services. For example, aggregate stability is indicative of three ecosystem services- climate resilience, flood risk mitigation and soil conservation. Importantly, inherent site characteristics, soil texture and vegetative features interact with soil characteristics to influence the supply of

Table 1. Ecosystem services and associated soil health indicators selected by the Vermont Soil Health and PES Working Group. Ecosystem services (column 1) flow to different scales of beneficiaries (column 2) and are influenced by ecosystem functions of healthy soils (column 3). The metrics selected by the working group (column 4) are measurable indicators of change in the ecosystem function, but the list is not comprehensive. Inherent site characteristics, soil texture and vegetative features interact with soil characteristics to influence the supply of ecosystem services (column 5).

Ecosystem Service	Beneficiaries	Ecosystem Function	Selected measurable indicators/ metrics	Mediating site & soil characteristics
Climate regulation	Global	Carbon storage	• Organic matter • Bulk density	• Soil texture • Drainage class • Soil moisture conditions • Artificial drainage
		Respiration	• CO_2 emissions from soil surface	
		Denitrification	• N_2O emissions from soil surface	
Downstream flood risk mitigation	Downstream communities	Infiltration	• Bulk density • Aggregate stability	• Location (proximity and position relative to water, connectivity) • Depth of soil • Soil type/texture • Slope • Artificial drainage
		Water storage	• Organic matter	
Soil conservation	Farm, Future generations, Downstream communities	Soil aggregation & cohesion	• Aggregate stability	• Depth of soil • Soil type/texture • Slope
Climate resilience	Farm & Foodshed	Available water capacity	• Organic matter	• Soil type/texture • Slope • Drainage • Depth of soil • Hydrologic connectivity
		Soil aggregation & cohesion	• Aggregate stability	
Biodiversity	Local & global	Foundation for other ecosystem functions & conserves genetic resources	• Biodiversity in soil	• pH • Soil texture • Land use history

many of these ecosystem services. While the flow of ecosystem services from any given site will be limited by those static characteristics, the selected indicators are sensitive to dynamic characteristics of soil that can be influenced by management. The degree to which static site and soil characteristics are taken into account in a PES program is an important decision for the working group to consider. The scope of this report is limited to documenting practical considerations for the five soil health indicators selected by the subcommittee:

1. Organic matter content
2. Bulk density
3. Aggregate stability
4. Greenhouse gas emissions from the soil surface (N_2O and CO_2)
5. Biodiversity in soil

Below, we explore these measurements as indicators of the ecosystem services important to Vermont and summarize important quantification considerations.

Table 2. Simplified table summarizing measurement considerations for each soil health indicator. These considerations are explored in depth in the report.

Indicator	Details	Who conducts test[1]	Cost	Scale	Feasibility	Accuracy
Organic matter	Loss on ignition	All soil testing labs	$4-8 per sample Labor costs: low.	Field	High (Commercial)	Medium
Bulk density	Collect intact soil cores and oven dry. Tools and training required.	UVM AETL, DairyOne	$8-10 per sample, three per field, plus additional tool costs. Labor costs: high.	Field	Moderate	High
Aggregate stability[2]	Assess % of water stable aggregates from either simulated rainfall or agitation in water	UMaine, Missouri Soil Health Center, Cornell, (could be added by UVM)	$10-$24 per sample Labor costs: low.	Field	High (Commercial)	Medium
GHG emissions from surface	Photoacoustic gas analyzer	Research technicians needed for frequent in-field measures	Direct measurement is cost prohibitive. Labor costs: high.	Field	Low	Low
	Modeled estimates[3] using COMET, Daycent or DNDC	Anyone can access COMET. Some models require technical knowledge or training.	The cost of modeling is time. Labor costs: high.	Field or farm	Moderate	Low
Biodiversity in soil[4]	Ecoplates: carbon substrate utilization test on a standard composite soil sample in lab	UVM research labs (Neher and Darby Labs, not commercial)	$30.00 per sample, plus lab tech time. Labor costs: moderate.	Field	Moderate	Moderate
	PLFA[5]: Phospholipid-derived fatty acid test on standard composite soil sample in lab	Missouri Soil Health Center, Ward Labs, Earthfort	PFLA is $50 - $80 per sample. Earthfort is > $100. Labor costs: low.	Field	High (Commercial)	Moderate
	Invertebrate monitoring: collection and identification of invertebrates or bait lamina test system	Soil ecologists (such as Deb Neher at UVM)	Generally expensive-- requires time, training and equipment. Labor costs: high.	Field	Moderate	Moderate

1. Laboratory links: University of Vermont Agricultural and Environmental Testing Lab: https://www.uvm.edu/extension/agricultural-and-environmental-testing-lab ; University of Maine Soil Testing Lab: https://umaine.edu/soiltestinglab/ ; Cornell Soil Health Lab: https://soilhealth.cals.cornell.edu/ ; Missouri Soil Health Assessment Center: https://cafnr.missouri.edu/soil-health/ ; Ward Laboratories: https://www.wardlab.com ; Earthfort Lab: https://www.earthfort.com
2. For aggregate stability, visual soil assessment or slake tests can be used in the field but are described qualitatively and are hard to compare across locations and over time.
3. Models do not include all possible management (grazing & vegetable systems are poorly represented)
4. Samples for biological analysis are time and temperature sensitive and require special handling. Deb Neher, soil ecologist from UVM should be consulted to design monitoring of soil biodiversity.
5. The Earth Fortification lab uses a test that is similar to PLFA-- considered more complex but more detailed.

CLIMATE REGULATION

Soil health influences *climate regulation* as an ecosystem service through its overall impact on the balance of atmospheric greenhouse gasses. This includes 1) the storage of carbon in soil that could otherwise be released as CO_2, 2) an increase in soil carbon that is sequestered from atmospheric CO_2, and 3) the release of greenhouse gasses during biologically mediated processes, such as CO_2 from respiration, and N_2O during denitrification. Methods for measuring soil carbon content are well established and broadly implemented. Methods for measuring greenhouse gas emissions from soils are challenging, require careful interpretation, and are generally expensive in technology and technician time. Improved technologies for measuring both are currently under development. Moderately accessible models for this ecosystem service at the field level exist but may not capture all management scenarios for Vermont.

Measuring soil carbon storage

A *soil carbon stock* is an amount of carbon in a known volume of soil. To calculate soil carbon stocks the *soil carbon content and bulk density must be known*. Stock estimates for different depths are not comparable, so establishing a standard depth is important. The standard depth of measurement for soil carbon stocks established by international standards is 30 cm,[5] and this is the depth to which soil carbon stocks were measured for the State of Soil Health project[6]. This differs from routine soil test depths in Vermont, which are generally taken to 15 cm.

Soil carbon is in two forms: organic and inorganic. Inorganic consists of mineral forms, whereas the organic carbon portion originates from living biological material and is the dynamic portion influenced by management. Organic carbon is approximately half of soil organic matter (conversion factor of 0.5)[7], and soil organic matter is routinely and easily measured in standard soil tests. Standard soil testing labs use the Loss on Ignition (LOI) procedure to measure organic matter content. This is a fairly accurate and low-cost test, and samples can be collected easily from the field without special equipment, and then submitted to a lab. Soil testing labs at UVM, and in neighboring states, are equipped to conduct this test[8]. As a stand-alone test, the cost per sample for LOI is within a range of $4-$8 from regional labs, including UVM, UNH, UMaine and DairyOne in Geneva, NY.

LOI measures the weight loss of dry samples subjected to an oven at ~360-375°C. A similar procedure called Dry Combustion, at a temperature of ~900°C can measure total carbon, inclusive of inorganic carbon. Dry Combustion is recommended by NRCS as more accurate[9], but is more costly, at $20 per sample from Cornell. Some researchers have pushed to use Walkey-Black wet chemical procedure to measure active carbon as an indicator of change. While the active carbon test is sensitive to early changes, it does not capture all forms of organic matter.

Bulk density is a measure of the physical mass of soil in a given volume. In order to measure bulk density, an undisturbed core is collected, oven dried and weighed. The metric for bulk density is the dry weight divided by the volume of the core (g/cm^3). A minimum of three cores per field should be collected. Bulk density for a given depth can be measured as an entire core of the given length, or as a stratified sample, with multiple short cores collected to represent the entire depth of interest. Specialized equipment for collecting undisturbed cores is available, and somewhat costly, at $400-$1000. Collecting the cores also requires more time than standard soil sampling. Based on our experience, depending on conditions this can take 1-4 hours per field using hand powered tools. Collecting undisturbed cores requires extra time and care to ensure the cores are collected in a uniform and comparable way. Processed samples in the lab costs approximately $5-$10 and is available locally from the UVM AETL and DairyOne. Collection of accurate bulk density samples requires training and skilled labor that should be accounted for on top of lab processing costs.

An alternative approach to measuring bulk density is build a local model that uses measured organic matter, soil texture, penetration resistance and soil moisture to estimate bulk density. A training dataset would need to be collected and used to build a predictive model. However, after the model was developed, bulk density could be inferred from these parameters that are easier to measure. This exact approach has not been used for a soil-health program, but several researchers have built reasonably accurate models linking soil characteristics, soil water content, penetration resistance and bulk density for various agricultural regions.[10,11]

New tools are currently under development using machine vision technology to provide rapid estimates of soil carbon content using a probe. Examples include Yard Stick[12], and Stenon[13]. Yardstick is currently undergoing field calibration in the US, and reports from Stenon technology calibration indicate it is inaccurate for soils with fine textures (clay), and only measures to a maximum of 3% soil organic carbon[14]. While the technology is not currently ready and suitable for Vermont soils, the Vermont Soil Health PES should keep apprised of this technology development, as well as the potential for near and mid infrared spectroscopy to reduce the costs of quantifying SOC content.

Measuring carbon sequestration

Soil carbon *sequestration* is the capture of atmospheric carbon in photosynthesis by plants, which is subsequently incorporated into the organic portion of soils through decomposition. If the additions of organic carbon are greater than the losses through respiration and harvest, a net gain in soil carbon can be achieved over time.

Measuring the change in soil carbon requires that evaluation be able to compare changes over time. This means that baseline data is needed, as well as follow up measurements at a later time. Changes in soil organic matter from management are detectable at multi-year intervals, often taking 3-5 years to show up in measurements. Soil organic matter also fluctuates seasonally, so it requires that sampling be conducted at the same time of year to confirm changes in soil carbon levels. Annual sampling would provide greater accuracy and help identify potential year-to-year variability. However, sampling at 2–3-year intervals would be sufficient.

Additionally, the origin of organic matter must be considered. Organic matter additions from offsite will influence soil carbon content, but in some cases may not always be considered as sequestration within the boundary of the field. This is an important consideration for PES program design. Farmers can reduce atmospheric carbon in two ways: by increasing the rate at which their land captures carbon, and/or by slowing the rate at which soil carbon returns to the atmosphere. Applying compost made off-site, for example, increases soil carbon content, but does not necessarily increase carbon uptake or reduce losses. On the other hand, growing high biomass cover crops can increase carbon uptake, and reduced tillage can reduce carbon losses. Building assessment or accounting tools for carbon being brought onto the farm may add accuracy but would likely add complexity in reporting and verification.

Changes in bulk density should likely not be included in calculations of carbon sequestration. A change in bulk density has opposite implications for the supply of other ecosystem services. Increases in bulk density would measure greater soil carbon stocks but reduced infiltration capacity. Reductions in bulk density would indicate increased infiltration but measure smaller carbon stocks. In order to eliminate a penalty in terms of carbon storage for farmers who reduce compaction in their fields, an assumed reference bulk density value could be used for carbon storage, otherwise the program may inadvertently incentivize compaction

Influence of site characteristics on soil carbon

Soil texture influences the capacity for sequestration and the upper limit of soil carbon content that may be achievable at any site. Finely textured clay soils have a high affinity for soil carbon and have higher soil carbon content when compared with coarse sandy soils. Figure 1 shows how recent organic soil carbon content measured on Vermont farms in the same production differs by soil texture. For Vermont PES, this means that *soil texture limits the potential for soil carbon content at each site, and expectations for sequestration should be differentiated by soil texture.*

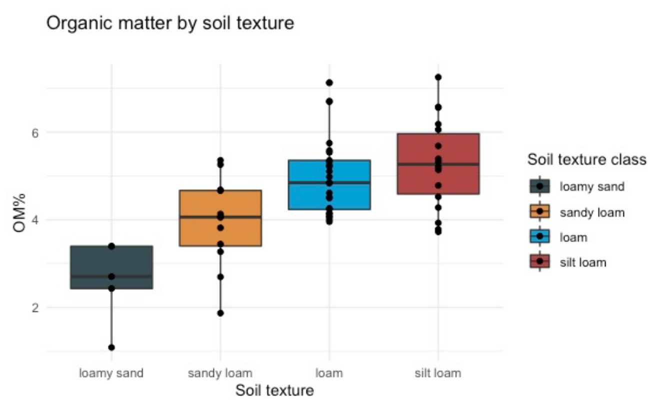


Figure 1. Soil organic matter content differs by soil texture. This data is from 60 corn fields in northwestern Vermont that participated in a Soil Health CIG study led by Dr. Heather Darby in 2020.

Measuring N_2O and CO_2 flux

Overall, measurement of gaseous flux from the soil surface requires costly equipment and staff time, and is impractical for monitoring and quantification in a Vermont Soil Health PES until technology changes significantly. Measurement tools can capture a subsample of gaseous flux from a point on the soil surface over a small time period. To estimate an annual impact on GHG flux, multiple measurements at multiple points in time must be collected and used to infer GHG flux across the field and between measurement times. A single photoacoustic infrared gas analyzer tool alone costs $500-$5,000.

Modeling climate regulation

Greenhouse gas emissions from soil, including nitrous oxide, carbon dioxide and methane, are highly sensitive to soil water and air conditions, and often occur in sharp pulses. Modelling these outcomes is complicated and subtle, and while there are important relationships between soil health parameters and gaseous emissions, these are not easily distilled. Developing estimates for how soil-health parameters (e.g., soil organic matter and bulk density) impact gaseous emissions would be best accomplished in complex, hard-to-use models such as DayCent or DNDC. The USDA's COMET-FARM model can generate predictions of greenhouse gas emissions from soil, based on a wide range of practices. However, COMET cannot incorporate changes in other soil-health indicators.

There is a lot of interest in estimating soil carbon based on imagery, but this has not proved accurate at local scales. In 2021, the Northwest Crop and Soils team at UVM Extension compared measured soil carbon stock data from the NRCS Rapid Carbon Assessment with NASA SMAP and UN FAO global soil carbon maps, but found no significant correlation. In order to use imagery to predict soil carbon content accurately, it would require extensive calibration and validation with local on-the ground measurements. For a Vermont PES, this means significant investment into sampling, analysis and development of a tool that could accurately infer subsurface soil characteristics from land cover images would need to take place, without knowing if the tool could even work accurately eventually.

DOWNSTREAM FLOOD RISK MITIGATION

Soils have the capacity to infiltrate, absorb store and retain water, and can therefore mitigate the storm water runoff volumes that impact peak flows, and potentially downstream communities' flood risks[15]. Enhanced soil health can influence the hydrologic response of agricultural fields and reduce storm water runoff volumes by altering the infiltration and water holding capacity of the soil. Biological activity and organic matter change the physical structure of soil and the way it interacts with water by increasing aggregation, pore space and the sponge-like characteristics of soil. Soil structure and the presence of macropores influence infiltration and drainage, but a field's proximity and connectivity to waterways, depth of soil, clay content, antecedent moisture condition, soil texture, surface cover and the presence of artificial drainage will also influence a field's potential to contribute to mitigating downstream flood risk. Finally, the relative location of a field to a downstream community determines if there is potential for delivery of flood risk mitigation as an ecosystem service.

Measuring indicators of downstream flood risk reduction

Tools to directly measure infiltration in the field exist but are time consuming to conduct and there are many challenges to ensuring accurate and comparable measurements. Bulk density, organic matter content and aggregate stability are indicators of the dynamic changes in soil structure that influence infiltration, that are more easily measured. Aggregate stability can be a predictor for infiltration rate because the two have been so well correlated[16]. However, clay content and bulk density have been shown to have a stronger influence on infiltration rates than aggregate stability[17], and organic matter content often plays a significant mediating role[18]. Thus, aggregate stability can be an indicator to complement other measures, but bulk density and organic matter content may be more direct indicators.

Bulk density is a measure of soil mass by volume, and an indicator of soil compaction[19]. A decrease in bulk density directly indicates an increase in pore space and infiltration capacity. Considerations for measuring bulk density are described in the Climate Regulation section above. Processing samples in the lab costs approximately $8-$10 per sample and is available locally from UVM AETL and Dairy One. Three cores should be taken from each field.

Increases in *organic matter* may have an effect on soil water content at saturation, field capacity and available water capacity. A recent meta-analysis of relevant research found that although there are studies that show large impacts of organic matter on soil water, there are also studies that document very limited effects[20]. On average, increasing a soil's organic matter content by 1 percentage point increases soil water content at saturation by 2.95 percentage points, and plant available water capacity by 1.16 percentage points, though this factor differs by soil texture[13]. Considerations for measuring organic matter content are described in the Climate Regulation section above. As a stand-alone test, the cost per sample for LOI is within a range of $4-$8 from regional labs, including UNH, UMaine and DairyOne.

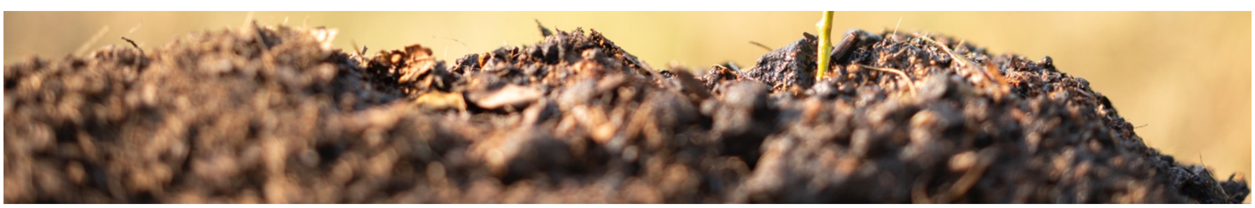
In the case of soil conservation, erodibility is only influenced by soil organic matter concentrations near the soil surface. Given the low costs of measuring soil organic matter, it may be feasible to take LOI measurement for different depths—one for the 0-15 cm layer, another for the 15-30 cm layer, and potentially deeper. This would allow the program to focus in on the impact that soil organic matter near the surface has on soil conservation, and give participating farmers insights into how soil carbon can be distributed through the soil profile. The depth of the A horizon may change. This is likely too complex to add to a PES program, but should be understood and considered to come degree. Erosion may reduce the depth of the A horizon, inputs or a reduction in bulk density may increase the depth of the A Horizon.

Aggregate stability is a measure of water-stable aggregates. It is expressed as the percent of aggregates of a specific size that withstand exposure to either a simulated rainfall event[21], or a submerged agitated water environment[22]. This is included as part of the Cornell Comprehensive Assessment of Soil Health and the University of Maine Soil Health testing packages, and also available from the Missouri Soil Health Testing program. Individual aggregate stability analysis from these labs cost $10 - $24, and may become available from UVM in the future. Comparisons of change over time need to use measurements from the same procedure, so switching between labs is unadvisable.

Modeling downstream flooding

The NRCS curve number method is the easiest and simplest tool for estimating how land-use impacts runoff. The method uses a lookup table and a simple calculation to generate estimates of runoff from a storm event with a given rainfall based on hydrological soil group, land use, and moisture condition. This method cannot directly incorporate soil health indicators.

As part of the Ecosystem Services Valuation Report (Task 5) we are using two methods to estimate soil-health impacts on downstream flooding: the Green-Ampt method and simple increase in soil water-holding capacity. The Green-Ampt method requires measures of porosity, plant available water capacity and saturated hydraulic conductivity. These indicators can be modelled based on soil texture, bulk density and organic matter content. By simulating a wide range of storms, on a wide range of soils and a gradient of soil-health indicators we will be able to create a simple tool to estimate the impacts of a given amount of soil-health improvement on runoff, that can be translated back into an impact on a curve number. For a simple method, we can assume that the major storms which result in large flood risk generate saturated conditions across most soils. From this, we can assume that reductions in flood flow due to soil health are proportional to the increase in unused plant available water capacity at the beginning of the flood event. Plant available water capacity can be modelled as a function of soil texture, soil organic matter and bulk density.



BIODIVERSITY

Soil biodiversity is a supporting ecosystem service that provides the foundation for the ecological processes and functions of the living portion of the soil[18]. The diversity of microorganisms and fauna in soil plays a central role in processes such as the formation of structure, degradation of pollutants, cycling of carbon and nutrients, decomposition, regulation of plant communities, disease suppression and pest regulation[23, 24].

Soil biodiversity measurements are often challenging to interpret and are only useful if understood relative to an optimal condition. Ideally, a locally relevant reference point from an undisturbed or desired site could be used as the optimal condition. Spatial set up of monitoring as well as sampling frequency and repeatability are important considerations for planning measurements. The FAO advises that soil biodiversity measures be "sensitive enough to reflect the influence of management and climate on long-term changes in soil quality but not be so sensitive as to be influenced by short-term weather patterns and robust enough not to give false alarm and be meaningful, resonant and easy to understand."[19]

The approaches to measuring soil biodiversity include broadly either measures of functional diversity or amount of biological activity. Functional diversity can be measured through carbon substrate tests, PLFA or invertebrate counts. Measures of the amount of biological activity, though not directly indicators of diversity, are sometimes inferred as indicators of diversity. This includes measures of microbial biomass and respiration (not explored in depth here).

Measuring microbial diversity

Ecoplates measure the metabolic activity of soil micro-organisms using 31 different carbon substrates. Soil from a standard composite soil sample must be moved on ice from the field to lab as quickly as possible. The soil is then put into solution and applied to a plate of 93 wells, with the carbon substrates in triplicate. The plate is incubated and read for the degree of metabolic activity and the number of substrates consumed. The results of Ecoplate analysis can be easily interpreted as a metabolic niche diversity index, a Shannon diversity index and a metabolic rate. Two labs at UVM have Ecoplate readers currently being used for research only, (Neher and Darby labs), but could potentially be accessed for a Vermont PES. Individual plates cost approximately $30.00, and with staff time, likely cost $35-40 per sample when processed in bulk.

Phospholipid-derived fatty acid (PLFA) tests offer a snapshot of the quantity of microbial biomass, and presence of certain functional groups, at the time of sampling. PFLAs are found in cell membranes, with certain fatty acids associated with different organisms. Quantifying these fatty acid contents in a soil sample can therefore indicate the size of specific microbial groups as well as the entire microbial biomass. The test indicates an amount of microbial biomass in g/g or nmol/g, and a functional group diversity index. The results can be used to estimate proportions of microbial types such as actinomycetes, arbuscular mycorrhizal fungi, rhizobia, saprophytic fungi and protozoa. Ward laboratories charges $80.00 per sample for PLFA, and the University of Missouri Soil Health Center charges $50.00 per sample.

Figure 2. An inoculated Ecoplate with 31 different carbon substrates in triplicate.

Earthfort Labs conducts a microscopy-based evaluation (not PLFA) that yields similar results, but costs upwards of $100 per sample. Results are not comparable across labs.

Monitoring soil invertebrates

Soil invertebrates play significant, but largely overlooked, roles in the delivery of ecosystem services. They are enormously diverse, from microscopic mites (Acari), to nematodes, springtails (Collembola), woodlice (Isopoda), earthworms (Haplotaxida/Lumbriculida) and beetles (Coleoptera). They perform a wide range of functions that contribute towards soil health, affecting organic matter decomposition and soil structure through shredding, microbial inoculation, and bioturbation activities, and influencing plant communities through selective herbivory. The breakdown of dead or decaying plant and animal material by invertebrate decomposers and detritivores provides a central input of nutrients and energy for soil processes. Invertebrates are sensitive to changes in soil conditions and are therefore valuable indicators of soil disturbance. Different taxa have varying sensitivities to soil characteristics, resulting in changes in taxa richness[25], but the overall abundance of soil invertebrates has also been shown to be affected. Invertebrates are abundant, relatively easy to sample and may respond quickly to soil disturbances. Samples can be extremely time and temperature sensitive and require someone knowledgeable to do identification.

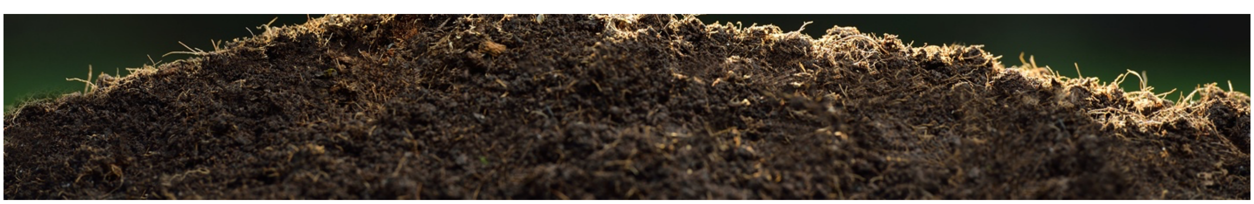
To extract *microarthropods* (Acari, Collembola, Enchytraeids), Berlese-Tullgren apparatus may be used whereby soil samples are placed on a gauze in a funnel with a heated light suspended above. As the heating and drying effect occurs, soil animals move down the funnel into a collecting vessel beneath. This method is cheap and straight-forward, but the processing of samples is limited by the number of funnels available, some organisms may desiccate before they can move out of the funnel. A Winkler extractor may also be used in which the soil sample is suspended in a mesh bag over a collecting vessel in ambient conditions (room temperature/no light). Pitfall traps (collecting vessels buried flush with the surface of the soil and left in place for 24 h) have been shown to be the most effective technique in capturing surface-active invertebrates including Diptera, Coleoptera, Chilopoda, Diplopoda, Hymenoptera and Orthoptera[26]. Training and dedicated facilities are required to do this procedure.

Earthworm densities are most effectively measured by a combination of extraction and hand sorting; however the application of formalin extraction is not recommended due to its toxicity. Extraction solutions using mustard or onion have been found to be effective, inexpensive and nontoxic alternatives.[27] Although hand sorting alone has reduced efficiency, particularly for deep-burrowing anecic species, it is a practical and achievable technique for farmers. Earthworms should be counted in early autumn or late spring, and not in extreme weather conditions or following manure/compost application. A 20 x 20 x 20 cm hole can be dug with a standard shovel, and the soil placed on a plastic sheet. The soil is searched by hand and earthworms are placed into a plastic bag, counted and recorded, and then replaced with the soil back into the hole. There are three functional groups of worms; epigeic (surface), endogeic (topsoil) and anecic (deep burrowing) and these may be easily identified and recorded with training. Basic earthworm counts can be more accessible than other invertebrate monitoring programs, but still require time and training.

Dung beetles (family Scarabaeidae) have an important role in dung decomposition and nutrient cycling on pastureland and can be identified by their clubbed antennae and strong paddle-like legs. Dung baited pitfall trapping, flotation, or visual searching may be used, all of which are inexpensive methods, although setting up pitfall traps may be time consuming. Dung beetle species and numbers vary according to the time of year, soil type, grazing management, shade and age of dung. A number of sampling sites should be selected to cover different habitats at set times of year. To perform simple counts, farmers may place a dung pat into a white tray and break it apart to count the beetles, or into a bucket of water whereby the beetles will float to the surface. However, these techniques will only sample endocoprid beetles (which live inside the dung pat) and not paracoprid beetles (which tunnel into the soil). Dung-baited pitfall trapping will attract a more accurate representation of these species. Dung beetles are slow moving and often play dead: fast moving species in dung are likely to be Hydrophilids or Staphylinids. Identification into functional groups (endocoprid and paracoprid) is important when considering ecosystem service provision and is straightforward based on body shape. Relative abundance of some invertebrates is not comparable across production systems. For example, dung beetles are important to assess in pastureland, but less so elsewhere.

Finally, the *bait lamina test system* may be used to assess both soil microbial and soil invertebrate activity, by using soil fauna feeding activity as a proxy. Bait lamina strips are 1 mm × 6 mm × 120 mm PVC strips which have sixteen 1.5 mm holes spaced 5 mm apart along their length. The holes are filled with a standard bait of cellulose powder, wheat bran and activated charcoal (70:27:3). Strips are inserted vertically into the soil and when removed, the proportion of bait eaten reflects the soil faunal activity in the soil. This technique provides a comparable and quick screening of soil biological activity, however may be somewhat costly ($500-$1000 per farm) and is strongly dependent on soil type and moisture.

All invertebrate monitoring methods described here require training in methods and identification, plus the time to conduct monitoring.

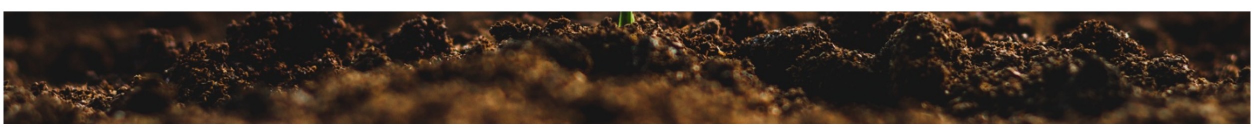


SOIL CONSERVATION & CLIMATE RESILIENCE

Soil conservation and climate resilience are complementary ecosystem services to those above. The indicators selected by the working group are also logical indicators of the potential for soil loss (erosion) during precipitation and flooding events (*aggregate stability*), and drought resilience (*organic matter content, bulk density, and aggregate stability*). Aggregate stability is a direct measure of soils' resistance to erosion from forces of water and is an appropriate indicator for soil conservation. Site and vegetative characteristics are also important here. Likewise, aggregate stability is a good indicator of the way enhanced soil heath contributes to soil resilience to heavy precipitation events. As well, greater soil available water capacity increases crop resilience to drought events, and while this is strongly influenced by soil texture, organic matter content, aggregate stability and bulk density are also indicators of soil water holding capacity. We consider them important, but auxiliary to the primary ecosystem services that the working group has focused on.

Modeling soil conservation

Soil loss (erosion) can be estimated using one of many versions of the Universal Soil Loss Equation (USLE). The MUSLE (Modified USLE) may be most useful for our purposes because it calculates the R (runoff) factor in a way that can allow us more flexibility to incorporate soil-health changes. RUSLE2 (Revised USLE) is already widely used in Vermont and can likely be transformed into the MUSLE[i]. Soil health indicators influence two components of this model. First, the soil erodibility factor (K) can be estimated using soil organic matter levels and soil intrinsic qualities, using existing empirical equations[28] [29]. Secondly, the USLE also uses total runoff and maximum runoff rate for each storm as an input. These parameters could be simulated through the methods described for flood control. A tool to estimate the soil K factor based on soil series and soil organic matter content could be developed relatively easily. Developing estimates of overall soil erosion changes due to soil-health based changes in infiltration and runoff would be a much more difficult task and would likely require extensive empirical or modelling research.



CONSIDERATIONS FOR CREATING A SOIL HEALTH INDEX

The PES work in Vermont is based on a concept of soil heath that is not a discrete characteristic or a single measurable attribute. While this reflects the dynamic and complex nature of life in the soil, translating that complexity into policy and programming could create a prohibitively complex PES program. However, if a single representative number or score could be determined to represent multiple metrics together, it could simplify a payment scheme. This concept is referred to as an index-- an index is a number that represents a combination of multiple metrics. The creation of a Soil Health Index for Vermont may be necessary in order to translate measures of multiple soil characteristics into appropriate PES program compensation.

The quest for a single number that could represent the combination of multiple attributes has been pursued by others, most prominently by the Cornell Assessment of Soil Health (CASH)[30]. Cornell's test created scores for each measured attribute, and an overall score based on all

[i] RUSLE calculates erosion as a function of rainfall energy, whereas in MUSLE the rainfall energy factor is replaced with runoff factors.

measured indicators. CASH scores reflect a soil's quality relative to a regional assessment conducted by Cornell researchers. These scores are nationally recognized and used as indicators of soil health in practice by farms and in academic publications.

The indicators selected for a PES program (Table 2) in this report overlap with the CASH test metrics to some degree. Aggregate stability and organic matter directly overlap with CASH. The CASH test uses a penetrometer to evaluate compaction, which measures soil physical characteristics similar to bulk density[ii]. Penetrometer readings are easier to take than bulk density samples, but are considered less accurate, especially in clay soils. The CASH test evaluates biological activity through measures of respiration and active carbon, which are related, but are not direct measures of soil biodiversity. The CASH test provides similar information to the indicators explored in this report and was developed collaboratively to harmonize soil health measurement protocols at the regional scale. The CASH test should be considered by the PES Working Group as an option for Vermont that would allow regional data comparisons, and has undergone extensive development.

The CASH, or similar SASH[31] approach, to indexing and creating scores relative to a regional baseline range could be applied for our work in Vermont. This requires determining an expected range for optimal performance from which to compare soil metrics, differentiated by soil texture. Test results could be given a ranking or score for each metric in relation to this optimal range. Determining ranks for each metric allows the diverse measurements to be compared and combined.

In order to create a single number to represent soil health in Vermont, an index that combines the measurements of interest would need to be developed. In this case, the working group would need to determine a rationale behind weighting of each soil health metric. This could be based on the ES valuation research being conducted for this project by T. Ricketts and B. Dube for Task 7, or through a facilitated process. The work to develop ranking and weighting should be undertaken with ample time, expertise and resources.

There are concerns that existing index tools that have been previously used in Vermont loose information valuable to farmers and are not useful for informing what changes should be made. Including a personalized explanation and break down to each farm could help the index be useful to farmers. Working group members have expressed interest in having each thing measured be considered, tracked, and reported separately. However, an index could simplify program payment design. Both types of information, the index and individual scores, could be developed and shared with farmers and PES program administrators.

[ii] Early development of the CASH test included bulk density as a recommended primary indicator of soil health. See: http://www.nnyagdev.org/PDF/SoilHealthFSPart2.pdf

CONCLUSION

In this paper we explored measurement and modeling implications for a pre-determined list of soil health indicators. Based on our research, four of the five metrics are feasibly measurable for a PES: aggregate stability, organic matter, bulk density and biological diversity. Notably, direct measurement of greenhouse gas emissions is cost prohibitive and not recommended for inclusion in measurement for PES. A program will either need to adopt a modeling approach, or drop this from the scope of the program. Greenhouse gas emissions from soil biological processes are highly influenced by management and in some cases can offset soil carbon gains towards climate regulation ecosystem services[32], so they should be included if possible. The research conducted for this report does not preclude the VT PES Working Group from changing or adding new soil health metrics of interest to their list.

Based on our research, there are some key decisions a PES program must make about the measurable indicators and analysis, and we outline them below. Aggregate stability and soil organic matter are the easiest and cheapest measurements to conduct and can be added to routine field soil sampling. Aggregate stability analyses differ by lab, so a commitment to a single procedure should be made. Measurements of bulk density and biodiversity are more costly and take more time. Consideration of the costs of this data against the value the data brings to the program should be carefully considered. Ecoplate analysis is the lowest cost approach for biodiversity assessment, but is not currently commercially available, so either some investment in making it available in Vermont needs to be pursued, or the more expensive PFLA test could be adopted. Alternatively, a lower cost measure of biological activity or abundance, rather than biodiversity could be adopted instead, but would not be an indicator of soil biodiversity.

Measurement costs for this suite of indicators will be approximately $200 to $300 per field total. Our research estimates the cost of laboratory analysis for all of the measurable indicators within a range $68 - $142 per field, plus approximately $150 in labor and equipment per field for bulk density and biological sample handling. Further work to determine the exact labor costs should be conducted. This labor estimate is based on our experience conducting the State of Soil Health sampling in Vermont in 2021, which used a human scale bulk density sampling equipment and batches of Ecoplates at UVM. Should a larger and more long-term sampling effort associated with the PES program be pursued, mechanized bulk density sampling equipment may save time and costs at scale in the long term. Farmer engagement in the sampling work may reduce the potential programmatic labor costs.

Should the PES Working Group decide to measure the other soil health indicators explored in this report as part of a PES program, there a few practical pathways for measurement and analysis that emerge from our research.

First, the Missouri Soil Health Center may be the only lab that currently commercially offers all of the desired metrics, including bulk density sample analysis, soil texture and PFLA for biological diversity [33]. A Vermont PES program could decide to use this lab at a cost of approximately $181 in total lab fees, plus the cost of bulk density sample collection and shipping, for a total up to approximately $300 per field. This is the simplest approach. However, the aggregate stability measures from this lab may not be comparable with the CASH aggregate stability results which have been widely used in Vermont already. Interpretation of those results for relevance in Vermont would still need to be developed.

Second, soil health testing services within Vermont (likely UVM AETL) could be expanded to provide commercially available analysis that meets the needs of a VT PES. The Missouri Soil Health Center was developed through a collaboration between the University of Missouri, NRCS and Missouri state agencies, and a similar approach could be used here. This could provide closer feedback and efficiency between sample analysis, interpretation for a PES program, and the ease of model development based on local data. Aggregate stability and a biological diversity analysis are the only things that would need to be added to the current AETL soil package. Upfront investments in laboratory capabilities would be needed, but its likely the per field lab analysis cost would be similar or less than the other approaches we've outlined, potentially down to $100 per field. Its possible the state could subsidize soil testing costs at this lab for farmers in Vermont as has been done in Missouri[34], or simply reimburse famers who participate in the program.

Third, the program could use a combination of the CASH test and another lab to measure all of the selected indicators. This is the approach that the Vermont State of Soil Health project took[6]. The cost per field for this project was approximately $250. The advantage in this scenario is that we can compare Vermont soil health metrics to soil health assessments nationally that also use CASH, and we could use the previously conducted CASH tests in Vermont (over 700), to develop a ranking and index. If we choose to develop a new test package, or use the Missouri lab, we will likely need to collect a new set of data in order to develop an expectation for optimal ranges.

For all of these scenarios, the interpretation of metrics for optimal ranges within the State of Vermont is needed. This is work that has been started by the Vermont State of Soil Health project[6], but would need to be refined for the PES needs. The consideration of whether soil health testing services within the state of Vermont should be improved to serve the needs of a Vermont PES is an important decision foundational to PES program development. This may have advantages for Vermont beyond the PES and has been recommended recently by UVM researchers[2].

Modeling has been adopted by other performance-based PES programs, and this offers an advantage of lower costs when compared to direct measurement. Our research shows that existing modeling tools can easily model the impacts of some of the soil health practices on the ecological processes of interest. The soil-health parameters that are feasible to measure - soil organic matter, aggregate stability and bulk density can also be used to predict changes in the ecological processes of interest. A practice-based program would require work to consolidate existing models into a single tool to streamline farmer data-entry. A performance-based program would require additional modelling and empirical work to build or modify a soil-health index, and estimate its relationship to the ecosystem processes we are interested in. Based on our work, we recommend that a new or modified models could reduce the costs of sampling for a PES program, however, field data must be collected to both develop some of these models or to input into the model in order to estimate other soil health parameters. The development of a soil health index is likely needed regardless of the extent to which a program uses modeling or measurement to inform payments.

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The University of Vermont

Field scale soil health scenarios

Vermont Payment for Ecosystem Services Technical Research Report #2

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

May 2022

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GUND INSTITUTE FOR ENVIRONMENT

THE UNIVERSITY OF VERMONT EXTENSION

Executive Summary

This report illustrates how changes in management on Vermont farms can influence soil health metrics at the field scale. We've used regionally relevant science-based scenarios to demonstrate how selected soil health metrics that are associated with ecosystem services could change on farms in response to management practices at the field scale. These field scale management scenarios demonstrate that many practices in use by farmers in Vermont can have positive impacts on the soil health indicators of interest to the Vermont Soil Health & Payment for Ecosystem Services Working Group. The scenarios document potential for tradeoffs among soil health properties. Specifically, some of the scenarios illustrate how bulk density and compaction can worsen in instances when other soil health properties improve. Long-term research that measures multiple indicators of soil health and ecosystem services on recommended soil health management practices in Vermont is needed to support the evidence-base for soil health and ecosystem services incentive programs.

The soil health outcomes from specific scenarios described in this report include:

Scenario #1: Best Management Practice Corn (No-till and Cover Crop)

- In replicated plot research on rocky silty loam soil, no-till & cover crop practices in corn silage systems resulted in significantly higher aggregate stability, organic matter, soil respiration, and an overall higher CASH soil health score than without these conservation practices.

Scenario #2: Corn hay rotation

- In long term replicated plot research on silt loam soil, organic matter, aggregate stability and soil respiration were all significantly greater in a corn-hay rotation compared to continuous corn. Soil health indicators overall were best in the rotation treatment in its first year out of hay.

Scenario #3a: Transition from annual cropping to rotational grazing

- In a transition from annual cropping to perennial pasture on clay loam soil, bulk density worsened and biological soil health indicators increased (β-glucosidase activity, microbial biomass carbon and potentially mineralizable N).

Scenario #3b: Restoring soil function with management-intensive grazing rotation

- Organic matter increased 2.75% over four years in a local management-intensive grazing system on clay and silty clay soils..

Scenario #4a: Vegetables with a soil building cover crop rotation

- A soil building cover crop rotation in a vegetable production system on silt loam soil had higher organic matter, surface hardness, aggregate stability, and active carbon than a continuously cropped system after 3-4 years.

Scenario #4b: Vegetable production with reduced tillage

- Reduced and no tillage treatments in vegetable plots on silt loam soil significantly increased aggregate stability and surface hardness after 3-4 years, though no significant difference in organic matter was detected.

Scenario #4c: Fertility practices in organic vegetable systems

- High compost rate treatments on a silty clay loam soil increased soil carbon and decreased bulk density in organic vegetable systems. High compost treatments also significantly reduced runoff, increased water holding capacity and demonstrated reduced nutrient loading.

Scenario #5a: Hayland with broadcast manure compared to incorporation with aerator

- A long term paired field trial on haylands on a Vermont farm with clay soils evaluated the use of an aerator prior to broadcasting manure. Overall CASH soil health scores increased in both fields, but to a greater extent in the aerated field. Organic matter, aggregate stability and respiration increased in both fields, more so in the control field.

Scenario #5b: Hayland with injected manure, with and without inhibitor

- In a randomized complete block treatment study of haylands on silt loam soils, manure application methods, nitrogen sources and inhibitor application did not influence N_2O or CO_2 fluxes from the soil surface.

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Introduction

This report illustrates how changes in management on Vermont farms can influence soil health metrics at the field scale. The report was written based on input from the Vermont Soil Health and Payment for Ecosystem Services Working Group and is intended to be informative and illustrative for members of the group.

We use regionally relevant science-based scenarios to demonstrate how soil health metrics and associated ecosystem services could change on farms in response to management changes at the field scale. Although the data presented is science-based, it is important to note that much of it is not generalizable. Measurable soil health outcomes are influenced by existing environmental and site conditions, management history, and soil texture, and are thus incredibly context dependent. Still, in light of this caveat, it is important for working group members to understand examples of how soil health metrics are influenced by soil management in Vermont. Whenever possible, we drew from research conducted in Vermont, or within the northeast region. Much of the information is based on studies that have been published in peer reviewed journals or technical reports.

For some soil health indicators it can take 5 to 7 years before changes are observed, and many of the studies were limited because they were short term (2 to 3 years). Some of the studies used replicated plot trials in their experimental design to establish statistical significance, while others tracked changes over time.

The information in this report is organized around the soil health metrics that were selected as indicators of ecosystem services by the working group's soil health subcommittee in 2021. These indicators are organic matter, aggregate stability, bulk density, greenhouse gas emissions and soil biodiversity. In this report, we first describe our approach briefly. Then, a brief description of the overall findings and a summary table highlight the way each scenario influenced the soil health metrics of interest. Finally, each scenario is described individually. An appendix shares the Comet Planner reports used to supplement the information on greenhouse gas emissions.

Methods

In October of 2021 PES Working Group members filled out a survey to identify the soil health scenarios that should be included in this report, and shared sources of data that could be used for the scenarios. The results of the survey were organized thematically, and then presented back to the Working Group for further feedback in an iterative manner. The final list of scenarios to be included in the report was determined in collaboration with the working group on November 16th 2021 with suggested data sources (figure 1).

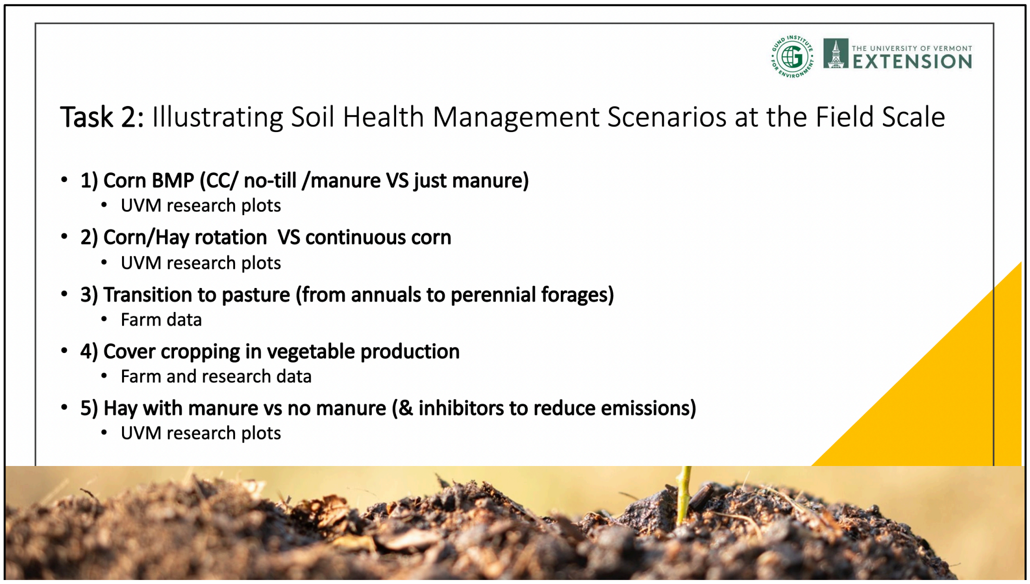

Figure 1. Preliminary list of soil health scenarios agreed upon for the report, as presented to the PES Working Group on November 16th.

For the first two scenarios, robust research data from UVM Extension's Borderview Research Farm was available which included most of the soil health metrics of interest. For the other scenarios, available studies often included only some of the soil health metrics of interest. Thus, we employed literature reviews and conversations with local experts to identify additional data that would provide a more complete perspective on how management can realistically influence soil health metrics at the field scale in Vermont. This process revealed a need for research on how organic vegetable production and pasture systems influence soil health and greenhouse gas emissions, as well as a dearth of information on soil biodiversity. Due to the lack of comprehensive studies that included multiple indicators for some systems, we included additional scenarios. Nine scenarios were ultimately included in this final report.

Greenhouse gas emissions data was rarely included in the referenced studies, so the NRCS Comet Planner tool was used to identify the directionality of impact on nitrous oxide emissions, carbon dioxide emissions and net carbon sequestration. The Comet Planner reports used for this are included in Appendix A.

Discussion

Overall, the available data we reviewed demonstrates that recommended practices which farmers are already using in Vermont can have measurably positive impacts on indicators of soil health. Different management practices effect different soil properties. In the scenarios, reduced tillage generally increased measures of aggregate stability. Applications of compost improved bulk density. Scenarios that featured increases in carbon-based inputs and residues, such as compost applications and cover cropping, demonstrated measurable increases in soil organic matter.

Organic matter, as a foundation of healthy soil was either improved in the scenarios we reviewed or demonstrated no measurable change over the time period of the studies. Improvements in soil carbon are known to take at last 5 to 7 years to detect, and this evidence should remind the PES Working Group to design a program that takes the long-term nature of investing in soil health into account.

Across the data we reviewed for this report, in no case were all of the indicators of interest measured in a single study, and in no case were all of the measured soil health indicators improved by a management scenario (Table 1). In some cases, the scenarios document potential tradeoffs among soil health properties. In particular, we observed many scenarios where practices were implemented and bulk density worsened-- this indicates soil compaction may need careful attention and greater educational focus within or alongside a PES program.

Greenhouse gas emissions were rarely measured, but the Comet Planner tool provided estimates of directionality and relative impact on overall climate regulation ecosystem services for all the scenarios we reviewed. Long-term research that measures multiple indicators of soil health and ecosystem services is needed to support the evidence-base for soil health and ecosystem services programs. This research could be built into the monitoring and verification aspects of a soil health PES program.

In our research for this report, we came across a dearth of studies relevant to the northeast on soil health and ecosystem services in vegetable production and pasture systems, as well as greenhouse gas emissions and comprehensive studies that included multiple indicators. Replicated plot research that includes a large suite of soil health metrics should be conducted to fill knowledge gaps about promising practices and inform the recommendations of a PES program.

Scenarios

Soil Health Scenario #1: Best Management Practice Corn (No-till and Cover Crop)

Scenario description	
Title of scenario	Best Management Practice Corn (No-till and Cover Crop)
Source of information	UVM Extension Northwest Crops and Soils Team Report based on research plots at Borderview Farm: 2020 Integrating Cover Crops and Manure into Corn Silage Cropping Systems by Dr. Heather Darby, UVM Extension Agronomist and Sara Ziegler, John Bruce, Ivy Krezinski, Rory Malone, and Lindsey Ruhl
Location and soil type	Borderview Research Farm in Alburgh, Vermont Benson rocky silt loam soil.
Land use and management history	Prior to implementation of this research, the area was planted with a variety of annual crops in a conventional tillage operation.
Detailed description of management/treatments and study design	The experimental design was a randomized complete block with replicated treatments of corn grown in various cropping systems. A best management practices (BMP) scenario of no-till and cover-cropped corn was grown alongside a 'business as usual' scenario with conventional tillage and no cover crop. Both treatments had spring applied manure. Other management treatments were included in this study but not described in this summary. Plots were 10' x 40' and replicated four times over three years. There were slight differences in dates, fertilizer application rates, and herbicide termination across the three years. In general, these were the order of events: Manure was surface applied to spring manure plots in early to mid-May at a rate of 6,000 gal/acre (+/- 200 gal) each year of the trial. In the conventional plots, manure was immediately incorporated using a disc harrow. Winter rye was planted at a rate of 100 lbs ac^{-1} at the end of September. In the spring, soil samples were collected for nitrate and soil health analysis with the Cornell Assessment of Soil Health (CASH) test package. Depending on the year, cover crop ground cover, height, and biomass was measured in late April to early May. Cover crops were terminated with herbicide in the no-till plots and in conventionally managed plots the cover crops were incorporated with a disc harrow. Corn was planted between mid-May and early June with a John Deere 7500 no-till corn planter at a rate of 34,000 seeds ac^{-1}. All corn plots received starter fertilizer. Soil samples were collected for PSNT analysis in the summer. Prior to corn harvest, corn populations were counted and samples were collected for CSNT (corn stalk nitrate test). Corn was harvested between early and mid-September. Samples were collected for yield and quality analysis by NIR.
Time period of data collection	3 years, Between fall of 2017 and the fall of 2020
Measured soil health outcomes	
Summary of influence on soil health	BMP practices resulted in higher aggregate stability, organic matter, soil respiration, and an overall higher CASH soil health score than business as usual (83.4, very high functioning vs 78.0, high functioning).
Directionality and measured extent of impact on selected soil health indicators:	

Organic matter	Over three years the accumulated effects were a net increase of 0.3% organic matter more in the BMP treatment than the conventional treatment. In 2020 the conventional, 'business as usual' treatment had 4.07% organic matter, and the BMP treatment had 4.37% organic matter.
Bulk density	Bulk density was not measured, but penetrometer data is used as a proxy. Penetrometer data in 2020 was not statistically significantly different among the treatments.
Aggregate stability	Over three years the accumulated effects were a net increase of 11.1% more in water stable aggregates in the BMP treatment than the conventional treatment. In 2020 the conventional, 'business as usual' treatment had 29.9% stable aggregates, and the BMP treatment had 41.0% stable aggregates.
N_2O & CO_2 emissions	Not measured. However, NRCS Comet Planner tool estimates that non legume cover crops cause small increases in nitrous oxide emissions that are offset by CO_2 reductions and carbon sequestration. It also estimates that no-till reduces nitrous oxide emissions. Considering, N_2O emissions, CO_2 emissions and carbon sequestration together, Comet Planner estimates the combination of cover cropping and no-till sequester a net equivalent of 0.68 tonnes CO_2e per acre per year.
Soil biodiversity	No measure of biodiversity was collected. However, indicators of biological activity were collected. Over three years the accumulated effects were a greater net increase of 0.170 mg CO_2 g $soil^{-1}$ in soil respiration in the BMP treatment than in the conventional treatment. In 2020 respiration in the conventional, 'business as usual' treatment measured : 0.567 CO_2 g $soil^{-1}$, and in the BMP treatment it was 0.737 CO_2 g $soil^{-1}$.
Additional Information	
Other data (yield, etc.)	Interactions: The 'business as usual' treatment increased in yield in 2019, despite cool wet spring conditions that delayed planting, before returning to a level similar to 2018 in 2020. In comparison, yields in from the BMP treatment had relatively steady yields, regardless of deviations in weather. While there was no significant difference in nitrate availability in the spring, PSNT levels in the summer were lower in the BMP scenario, which may have impacted yields. Overall, the 'business as usual' treatments produced an average of 21.6 tons ac^{-1}. On average, that is 3.3 tons ac-1 more than the BMP treatment (18.3 tons ac^{-1}). Crude protein was 0.65% higher in the 'business as usual' (9.50%) than the BMP (8.85%) treatment. There were no significant difference in other commonly measured quality metrics. It is important to note that in this study, aggregated over three years, higher soil health does not necessarily translate to higher yields or yield with higher quality.
Data limitations	Data was averaged over three years to reduce year-to-year variability. 2020 is the third year in no-till for the no-till plots. It may take several years before full effects of no-till on soil health is realized, and the averaging approach to addressing interannual variability in soil measurements limits the degree to which we can see improvements over time. This data reflects measurements that are subject to influence by soil type, environment, timing, and management history and therefore may not be representative of many fields.
References	Full report of the study is available. Darby, Heather et al., (March 2021). Integrating Cover Crops and Manure into Corn Silage Cropping Systems. University of Vermont Extension, Northwest Crops and Soils Program. https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2020%20Research%20Reports/2020_Integrating_Cover_Crops_and_Manure_into_Corn_Silage_Cropping_Systems_updated.pdf

Soil Health Scenario #2: Corn hay rotation

Scenario description	
Title of scenario:	Corn hay rotation
Source of information	UVM Extension Northwest Crops and Soils Team Report based on long term research plots at Borderview Farm: 2020 Corn Cropping Systems to Improve Economic and Environmental Health.
Location and soil type:	Borderview Research Farm in Alburgh, Vermont Amenia silt loam, 0-2% slope
Land use and management history:	Long term research plots since 2008, previously in corn or alfalfa/fescue
Detailed description of management or treatments and study design:	Replicated treatment plots monitored soil health in long-term corn-hay rotations alongside a continuous tilled corn treatment, and other corn cropping treatments. The experimental design was a randomized complete block with replicated treatments of corn grown in various cropping systems. No manure was used in this trial. Two corn-hay rotation treatments, in a 5-year hay to 5-year corn rotation, were part of this study. The only difference between them being that they are on different years in the rotation. In 2020, one of the corn-hay treatments rotated into hay from corn, and the other from corn to hay. All plots in the trial received a spring fertilizer application of 300 lbs ac^{-1} of 19-19-19. The continuous corn is plowed in early May. In year one rotation plots, after the first perennial forage cut, herbicide was sprayed to terminate the perennial forage and then seeded with corn. Corn was seeded in 30” rows at 34,000 seeds ac^{-1} with a 92 days variety. At planting, 200 lbs ac^{-1} of an 10-20-20 starter fertilizer was applied to all corn plots. For rotation into sod, treatments that were planted in corn since 2014 were tilled in early May and planted the next day with a perennial forage mix of 60% alfalfa and 40% tall fescue at a rate of 20 lbs ac^{-1}. Corn plots received spring herbicide weed control and were side-dressed with broadcast nitrogen in June at rates according to PSNT-based recommendations. Soil health was measured annually using the Cornell Assessment of Soil Health test and bulk density was measured to 30 cm depth in each plot in year 2021. Forage yield and quality were assessed each year for both annual corn and perennial forage.
Time period of data collection:	Research on this trial has spanned 11 years, 2012 – 2021
Measured soil health outcomes	
Summary of influence on soil health:	Organic matter, aggregate stability and soil biological activity (measured through respiration) were all significantly greater in the corn-hay rotation compared to continuous corn. Soil health indicators overall were best in the rotation treatment in its first year out of sod. Bulk density was not different between treatments.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	Corn-hay rotation had a net additional 0.25% to 1.22 % organic matter compared to continuous corn treatment (significant to p=0.1). In 2021 organic matter content was 3.31% in the continuous corn treatment, 4.53% in the rotation treatment that was coming out of 5 years hay and 3.55% in the rotation treatment that was coming out of 5 years corn. No manure was added in this trial, so organic matter increases are primarily due to crop residues.
Bulk density	No significant difference observed between treatments for bulk density samples collected in 2021.

Aggregate stability	Corn-hay rotation had a net additional 9.4% to 41.3 % aggregate stability compared to continuous corn treatment (significant to p=0.1). In 2021 aggregate stability was 33.3% in the continuous corn treatment, 74.6% in the rotation treatment that was coming out of 5 years hay and 42.7% in the rotation treatment that was coming out of 5 years corn.
N_2O & CO_2 emissions	Not measured. However, NRCS Comet Planner estimates that adding perennial crop rotation reduce nitrous oxide emissions.
Soil biodiversity	No measure of biodiversity was collected. However, indicators of biological activity were collected. Corn-hay rotation had an additional 0.489 to 0.623 CO_2 g soil^{-1} respiration compared to continuous corn treatment (significant to p=0.1). In 2021 respiration was 0.537 CO_2 g soil^{-1} in the continuous corn treatment, 1.16 CO_2 g soil^{-1} in the rotation treatment that was coming out of 5 years hay and0.671 CO_2 g soil^{-1} in the rotation treatment that was coming out of 5 years corn.
Additional Information	
Other data (yield, etc.)	No significant difference between corn yields was detected. Higher dry matter content and quality characteristics were detected for the corn in its first year out of hay, but could have been attributed to a later planting date that was not impacted by late frost a compared to the other corn plots. Other corn system treatments in this study included tilled corn with cover crop, no-till corn, and no-till with winter cover crop.
Data limitations	This data reflects measurements that are subject to influence by soil type, environment, timing, and management history and therefore may not be representative of all fields.
References:	A full report of the trial results is available online: Darby, H., Ruhl, L., Malone, R and S. Ziegler. (January 2021). 2020 Corn Cropping Systems to Improve Economic and Environmental Health. University of Vermont Extension, Northwest Crops and Soils Program. https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2020%20Research%20Reports/2020_Corn_Cropping_Systems_Report_VIRECA.pdf

Soil Health Scenario #3a: Transition from annual cropping to rotational grazing

Scenario description	
Title of scenario	Transition from annual cropping to rotational grazing
Source of information	Shawver, C. J., Ippolito, J. A., Brummer, J. E., Ahola, J. K., & Rhoades, R. D. Soil health changes following transition from an annual cropping to perennial management-intensive grazing agroecosystem. *Agrosyst Geosci Environ*. 2021; 4:e20181. https://doi.org/10.1002/agg2.20181
Location and soil type	Colorado State University Agricultural Research, Development and Education Center, Fort Collins, CO 80524. Clay loam soil.
Land use and management history	Pasture rotational grazed since 2017, converted to perennial pasture 2016. Tilled cropping system (corn, silage, dry beans, alfalfa) prior to that.
Detailed description of management/treatments and study design	The field was planted with grass-legume mix in 2016 and cross drilled with legumes in 2017. The field was 82 hectares with a central pivot irrigation system, which was split into 32 paddocks for grazing with animals that were moved every 1-4 days to leave 50% forage behind. Soil samples were collected on 15 randomly selected paddocks (30 soil cores per replicate), in May 2017 and again in May 2018. The Soil Management Assessment Framework (SMAF) assessment tool was used.
Time period of data collection	2017-2018
Measured soil health outcomes	
Summary of influence on soil health	Physical soil health indicators decreased between 2017 and 2018 (bulk density increased, water stable aggregates did not change). Biological soil health indicators increased between 2017 and 2018 (β-glucosidase activity, microbial biomass carbon and potentially mineralizable N).
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	No change in soil organic carbon was detected between years
Bulk density	Bulk density increased between 2017-2018.
Aggregate stability	No change in water stable aggregates was detected between years.
N_2O & CO_2 emissions	Not measured. However, NRCS Comet Planner estimates that the conversion to forage and biomass plantings would reduce nitrous oxide emissions.
Soil biodiversity	Increases in soil biological activity (β-glucosidase activity, microbial biomass carbon and potentially mineralizable N) were observed.
Additional Information	

Other data (yield, etc.)	Reduction in nutrient soil health indicators between 2017-2018 due to reduction in extractable P concentrations, although extractable K concentrations increased over time.
Data limitations	This experiment was conducted in the arid climate of Colorado, so has limited transferability to Vermont. Data only shows the impact of one grazing season, because measurements were taken before grazing began in May 2017 and then before the second grazing year began in May 2018.
References	Shawver, C. J., Ippolito, J. A., Brummer, J. E., Ahola, J. K., & Rhoades, R. D. Soil health changes following transition from an annual cropping to perennial management-intensive grazing agroecosystem. *Agrosyst Geosci Environ*. 2021; 4:e20181. https://doi.org/10.1002/agg2.20181 Contosta, A. R., Arndt, K. A., Campbell, E. E., Grandy, A. S., Perry, A., & Varner, R. K. (2021). Management intensive grazing on New England dairy farms enhances soil nitrogen stocks and elevates soil nitrous oxide emissions without increasing soil carbon. *Agriculture, Ecosystems & Environment*, *317*, 107471.

Soil Health Scenario #3b: Restoring soil function with management-intensive grazing rotation

Scenario description	
Title of scenario	Restoring soil function with management-intensive grazing rotation
Source of information	UVM Extension, Center for Sustainable Agriculture, Pasture Program, based on 5-year research at Philo Ridge Farm.
Location and soil type	Philo Ridge Farm in Charlotte, Vermont, 05445 Vergennes and Covington clay soils. Clay & silty clay
Land use and management history	Until 2012, Philo Ridge Farm (former Foote Farm, owned by the Foote family for six generations) operated as a conventional dairy known as Foote Farm, where fields were rotated with corn, alfalfa, and hay. In 2012, 400-acre Philo Ridge Farm began an ecological farming project, and a few years later, the farm started to incorporate diversified agricultural practices working to improve the pastures utilizing high-stock density grazing on every pasture to produce meat, wool, fruits and vegetable crops.
Detailed description of management/treatments and study design	No known soil amendments, other than high-stock density grazing animal effect was applied between 2015-2017. Each animal unit, AU can return in average about 250 lb of N and over 100 lb of P, K and Ca respectively via manure and urine, per year. Grazing animals, grazed 1/3 to 1/2 of the pre-grazing forage of each paddock subdivision for one day, resting until the pasture recovered between 20 and 45 days. On-farm compost application started to be applied in selected areas of hayfield(s) after 2017. Repeated measurements of 25 cm-deep soil cores (x ~50 cores per field) were taken from every hay and grazing fields of the farm, during 2015, 2017, 2019 and 2021. Soil chemistry was assessed for pasture and hay at the University of Vermont Ag. Testing Lab and soil biological diversity at Earth Fortifications Laboratory. Comprehensive measurements of soil biological diversity (ciliates, flagellates, amoeba, mycorrhizae, active bacteria, total bacteria, active fungi, total fungi, fungi hyphae diameter, bacteria/fungi ratio) was collected from every field, but not reported at this time. Bulk density and penetrometer data on one field was measured, but is not reported at this time. One hayfield that has never been grazed will be used a control comparison when the study is published, but is not reported here.
Time period of data collection	Whole farm soil data collection spanned from 2015 to 2021, data collected every 2 years (2015; 2017; 2019, and 2021).
Measured soil health outcomes	
Summary of influence on soil health	Organic matter, and other soil macro and micronutrients, and biological activity changed after applying management-intensive grazing between 2015 and 2019 (2021 data still pending).
Directionality and measured extent of impact on selected soil health indicators:	

Organic matter	Preliminary data shows an increase of soil organic matter across the farm of 1.91% between 2015 and 2017, 0.84% between 2017 and 2019, (2.75% between % between 2015 and 2019). 2021 data has not been analyzed yet, as soil tests just arrived from the soil's laboratory.
Bulk density	Not reported.
Aggregate stability	Not reported.
N_2O & CO_2 emissions	Not measured. Not enough information exists to project the impact of rotational grazing on nitrous oxide emissions, but recent research on organic pastures in the Northeast suggests N_20 emissions can offset soil carbon gains in some, but not all cases (Contosta et al., 2021).
Soil biodiversity	Not reported.
Additional Information	
Other data (yield, etc.)	Significant difference in organic matter increase were found over time in some of the fields, after management intensive grazing was implemented across the farm in 2016, especially on hayfields, old corn-alfalfa fields and other grazing fields was detected.
Data limitations	What is reported here from this study is longitudinal observational data, tracking indicators over time, and does not include comparisons to a control treatment. This data reflects measurements that are subject to influence by soil type, environment, timing, and management history and therefore may not be representative of all fields.
References	Data and information based 2015-2021 UVM Extension, Juan Alvez field experiments at Philo Ridge Farm; currently working on manuscript preparation. Contact Juan with any questions. Juan.Alvez@uvm.edu

Soil Health Scenario #4a: Vegetables with a soil building cover crop rotation

Scenario description	
Title of scenario	Vegetables with a soil building cover crop rotation
Source of information	Idowu, O. J., Van Es, H. M., Abawi, G. S., Wolfe, D. W., Schindelbeck, R. R., Moebius-Clune, B. N., & Gugino, B. K. (2009). Use of an integrative soil health test for evaluation of soil management impacts. *Renewable Agriculture and Food Systems*, *24*(3), 214-224.
Location and soil type	The study was conducted at the Gates experimental farm in Geneva, NY on Kendaia silt loam and Lima silt loam soils.
Land use and management history	The soil had been in continuous vegetable rotation as part of a commercial operation for many years.
Detailed description of management/ treatments and study design	The study site consisted of 72 plots over 6 hectares with three tillage, three cover crop and two rotation treatments. Tillage treatments included no till (NT), zone-till (ZT), and a full till scenario of both mouldboard and discing (PT). The three cover crop treatments were no cover, rye and vetch. The first rotation involved continuous high-value vegetable cropping, while the second rotation incorporated season-long soil-building crops. Cover crops were established in early fall and killed with glyphosate in the spring. A zone builder with a deep ripping shank to 0.3 m established the zone tillage (ZT) treatments each spring with 0.015 m wide planting zones. The PT treatment used mouldboard plowing and discing each spring to prepare a seedbed. The continuous cropping sequence was bean – beet – sweet corn – cabbage. The soil building rotation was bean – field corn – clover/barley – sweet corn – bean. To isolate the impact of rotations for this scenario report, we selected data from the PT (mouldboard and discing) and no-cover treatments for both rotations to highlight the impact of the rotation on soil health indicators. The tillage treatment impacts are highlighted in Scenario 4b.
Time period of data collection	The experiment was established in 2003 and soil samples were collected in 2006 and 2007
Measured soil health outcomes	
Summary of influence on soil health	After 3-4 years in different rotations organic matter, surface hardness, aggregate stability, active carbon were higher in the soil building rotation.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	At the end of the study organic matter content was higher by 0.2% in the soil building rotation. Organic matter was 2.2% in the continuous vegetable treatment, and 2.4% in the soil building rotation treatment.
Bulk density	Bulk density was not measured, but penetrometer data is used as a proxy. Surface and subsurface hardness were higher in the soil building rotation than the continuous cropping plots at the end of the experiment. At the end of the experiment, surface hardness in the continuous vegetable treatment was 0.85 Mpa and 1.19 Mpa in the soil building rotation treatment. Subsurface hardness in the continuous vegetable treatment was 1.90 Mpa and 2.13 Mpa in the soil building rotation treatment.
Aggregate stability	At the end of the experiment, aggregate stability was 5.1% higher in the soil building treatment than in the continuous cropping treatment. Aggregate stability in the continuous vegetable treatment measured at 14.4% in the final year, and was 19.5% in the soil building rotation treatment.

N_2O & CO_2 emissions	Not measured. However, NRCS Comet Planner tool estimates that perennial crop rotations reduce nitrous oxide emissions.
Soil biodiversity	Soil biodiversity was not measured but active carbon can be used as an indication of biological activity. At the end of the experiment active carbon level were similar, but slightly higher in the soil building rotation. Active carbon in the continuous vegetable treatment was 516 mg/kg, and in the soil building rotation treatment was 539 mg/kg.
Additional Information	
Other data (yield, etc.)	The experiment identified significant impacts of cover crops treatments on surface hardness and potentially mineralizable nitrogen, and suggested that longer term studies would be needed to detect the impact of covers crops on other soil health indicators. Tillage had significant effects on many indicators, which are summarized in Soil Health scenario 4b.
Data limitations	The 72 plot experiment was complex and the rotation treatments were not evaluated against each other for significant differences. Thus, the implications of this observation are limited, but useful for illustration. The use of glyphosate to kill down cover crops does not reflect dominant management trends among vegetable growers in Vermont. Additionally, some soil health outcomes, especially soil organic matter, take a long time to show detectable changes and this study may have been to short (3-4 years) to capture that.
References	Idowu, O. J., Van Es, H. M., Abawi, G. S., Wolfe, D. W., Schindelbeck, R. R., Moebius-Clune, B. N., & Gugino, B. K. (2009). Use of an integrative soil health test for evaluation of soil management impacts. *Renewable Agriculture and Food Systems*, *24*(3), 214-224.

Soil Health Scenario #4b: Vegetable production with reduced tillage

Scenario description	
Title of scenario	Vegetable production with reduced tillage
Source of information	Idowu, O. J., Van Es, H. M., Abawi, G. S., Wolfe, D. W., Schindelbeck, R. R., Moebius-Clune, B. N., & Gugino, B. K. (2009). Use of an integrative soil health test for evaluation of soil management impacts. *Renewable Agriculture and Food Systems*, *24*(3), 214-224.
Location and soil type	The study was conducted at the Gates experimental farm in Geneva, NY on Kendaia silt loam and Lima silt loam soils.
Land use and management history	The soil had been in continuous vegetable rotation as part of a commercial operation for many years.
Detailed description of management/ treatments and study design	The study site consisted of 72 plots over 6 hectares with three tillage, three cover crop and two rotation treatments. Tillage treatments included no till (NT), zone-till (ZT), and a full till scenario of both mouldboard and discing (PT). The three cover crop treatments were no cover, rye and vetch. The first rotation involved continuous high-value vegetable cropping, while the second rotation incorporated season-long soil-building crops. Cover crops were established in early fall and killed with glyphosate in the spring. A zone builder with a deep ripping shank to 0.3 m established the zone tillage (ZT) treatments each spring with 0.015 m wide planting zones. The PT treatment used mouldboard plowing and discing each spring to prepare a seedbed. The continuous cropping sequence was bean – beet – sweet corn – cabbage. The soil building rotation was bean – field corn – clover/barley – sweet corn – bean.
Time period of data collection	The experiment was established in 2003. Soil samples were collected in 2006 and 2007.
Measured soil health outcomes	
Summary of influence on soil health	Reduced tillage treatments significantly increased aggregate stability and surface hardness. After 3-4 years, no significant difference in organic matter was detected in this study. Active carbon was significantly reduced in the no till treatment only in the continuous rotation.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	No significant differences in organic matter were detected in this study. At the end of the study, organic matter in the full tillage treatment was 2.2% in the continuous rotation, and 2.4% in the soil building rotation. Organic matter in the zone tillage treatment was 2.1% in the continuous rotation, and 2.0% in the soil building rotation. Organic matter in the no tillage treatment was 1.9% in the continuous rotation, and 2.2% in the soil building rotation.
Bulk density	Bulk density was not measured, so penetrometer data is reported as a proxy. Surface hardness was significantly higher in the no till than the other two tillage treatments in the soil building rotation ($p<.01$), and significantly higher in zone till than full till in the continuous rotation. Surface hardness in the full tillage treatment was 0.85Mpa in the continuous rotation, and 1.19Mpa in the soil building rotation. Surface hardness in the zone tillage treatment was 1.10Mpa in the continuous rotation, and 1.20Mpa in the soil building rotation. Surface hardness in the no tillage treatment was 0.99Mpa in the continuous rotation, and 2.01Mpa in the soil building rotation.

	No significant difference was detected in subsurface hardness. Subsurface hardness in the full tillage treatment was Mpa in the continuous rotation, and Mpa in the soil building rotation. Subsurface hardness in the zone tillage treatment was Mpa in the continuous rotation, and Mpa in the soil building rotation. Subsurface hardness in the no tillage treatment was Mpa in the continuous rotation, and Mpa in the soil building rotation.
Aggregate stability	Aggregate stability was significantly higher in the zone tillage treatment continuous rotation, and the no till treatment was significantly higher in aggregate stability in the soil building rotation ($p<0.05$). Aggregate stability in the full tillage treatment was 14.4% in the continuous rotation, and 19.5% in the soil building rotation. Aggregate stability in the zone tillage treatment was 19.8% in the continuous rotation, and 19.8% in the soil building rotation. Aggregate stability in the no tillage treatment was 16.0% in the continuous rotation, and 26.4% in the soil building rotation.
N_2O & CO_2 emissions	Not measured. However, NRCS Comet Planner tool estimates that reduced and no-till decrease nitrous oxide emissions.
Soil biodiversity	No indicator of biological diversity was monitored. The best indicator of biological activity used in this study was active carbon. Active carbon in the full tillage treatment was 516mg/kg in the continuous rotation, and 539mg/kg in the soil building rotation. Active carbon in the zone tillage treatment was 550mg/kg in the continuous rotation, and 509mg/kg in the soil building rotation. Active carbon in the no tillage treatment was 437mg/kg in the continuous rotation, and 553mg/kg in the soil building rotation. Active carbon was significantly reduced in the no till treatment only in the continuous rotation.
Additional Information	
Other data (yield, etc.)	Potentially mineralizable nitrogen, phosphorus, potassium and zinc were significantly higher in the zone tillage treatment in the continuous cropping rotation.
Data limitations	Replicated plot research is capable of detecting the significant impacts of management on soil health outcomes. However, some soil health outcomes, especially soil organic matter, take a long time to show detectable changes and this study was to short (3-4 years) to capture that. Additionally, the use of glyphosate to kill down cover crops does not reflect dominant management trends among vegetable growers in Vermont.
References	Idowu, O. J., Van Es, H. M., Abawi, G. S., Wolfe, D. W., Schindelbeck, R. R., Moebius-Clune, B. N., & Gugino, B. K. (2009). Use of an integrative soil health test for evaluation of soil management impacts. *Renewable Agriculture and Food Systems*, *24*(3), 214-224. https://www.cambridge.org/core/journals/renewable-agriculture-and-food-systems/article/abs/use-of-an-integrative-soil-health-test-for-evaluation-of-soil-management-impacts/D7D791B872A8B69750ADE3669F1B9546

Soil Health Scenario #4c: Fertility practices in organic vegetable systems

Scenario description	
Title of scenario	Fertility practices in organic vegetable systems
Source of information	Evanylo, G., Sherony, C., Spargo, J., Starner, D., Brosius, M., & Haering, K. (2008). Soil and water environmental effects of fertilizer-, manure-, and compost-based fertility practices in an organic vegetable cropping system. *Agriculture, ecosystems & environment*, *127*(1-2), 50-58.
Location and soil type	The study was established at Virginia Tech's Northern Piedmont Agricultural Research and Education Center (NPAREC) in Orange, Virginia on a Fauquier silty clay loam soil with a slope of 7–10%.
Land use and management history	The land was previously used for research and education trials.
Detailed description of management/treatments and study design	Replicated plots of eight treatments evaluated the agronomic and environmental effects of various fertilizer and compost additions in organic vegetable systems. Treatments described in the experiment included: • CTL, Control (no amendments) • F, Fertilizer (soil test laboratory recommended rates of inorganic N, P, and K fertilizers, applied annually) • LC, Low compost (20% of the agronomic N compost rate applied annually • LCF, Low compost + fertilizer (20% of the agronomic N compost rate plus supplemental fertilizer required to meet crop N needs, applied annually) • AC, High compost (agronomic N compost rate, applied annually) • BC, High compost (agronomic N compost rate, applied biennially, i.e., in years 1 and 3) • BCF, High compost + fertilizer (Agronomic N compost rate applied biennially, i.e., years 1 and 3, plus supplemental fertilizer required to meet crop N needs) • PL, Poultry litter (agronomic N poultry litter rate, applied annually) Amendments were analyzed and then applied at rates to meet either all crop N needs or 20% of crop needs. Chemical analyses and rates are detailed in the publication. Amendments were hand-applied during seedbed preparation, and incorporated within 24 hours with a rototiller. The plots were cropped over three seasons with pumpkins in 2000, then corn in 2001, and then bell pepper in 2002. Winter rye was planted as a cover crop, and weeds were controlled using rototilling to 10cm and mulching with barley straw. The mulch straw was analyzed and estimated to add 14,882 kg C /ha, 161 kg N /ha, and 85 kg P /ha, as it was incorporated along with the rye in the spring. Potassium bicarbonate was used to control fungal disease in the pumpkins. Mineral oil was applied to corn tips, and parasitic wasps were released in 2001 to control pests. Trickle irrigation was used when necessary to prevent crop failure. Composite soil samples were collected each fall to assess soil chemical properties. An on-farm soil quality test kit was used to evaluate bulk density, porosity and soil moisture. Lysimeters were installed to evaluate N losses in subsurface runoff from the CLT, AC, PL and F treatment plots. A rainfall simulation and runoff collection event was run on the same treatments to evaluate runoff water quality and quantity.
Time period of data collection	2000-2002

Measured soil health outcomes	
Summary of influence on soil health	The high compost rate treatments (AC, BC, BCF) increased soil carbon and decreased bulk density. High compost treatments also significantly reduced runoff, increase water holding capacity and demonstrated reduced nutrient loading.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	The high compost rate treatments (AC, BC, BCF) increased soil carbon above the other treatments. Soil carbon content did not differ significantly between low compost rate treatment and the controls (CTL and F).
Bulk density	High compost rate treatments reduced bulk density notably within two seasons (AC, BC, BCF) when compared to the control and fertilizer treatment (CTL and F). Low compost rate applications decreased bulk density noticeably after 3 years.
Aggregate stability	Not measured.
N_2O & CO_2 emissions	Not measured. NRCS Comet Planner estimates increased nitrous oxide emissions from manure and compost amendments. However, considering, N_2O emissions, CO_2 emissions and carbon sequestration together, these practices are generally net carbon sinks.
Soil biodiversity	Not measured.

Additional Information	
Other data (yield, etc.)	High compost treatments increased water holding capacity after 3 years. Pumpkin and bell pepper yields were unaffected. Corn yields were higher in LCF, AC, BCF, PL and F than in the control, low compost and biennial compost treatments. Nitrate leachate analysis indicates that annual application of fertilizer at rates designed to provide plant available N will not impair groundwater quality, and have a similar impact as unamended treatments. Nutrient management planning can prevent subsurface N losses. Compost amended soil (AC) demonstrated an improved ability to absorb water, with some treatments allowing significantly more water to percolate into and be held by soil, and delayed commencement of runoff, due to decreased bulk density. Particulate concentrations (TSS) in runoff were higher in the control and fertilizer treatments. Compost-amended soil contributed the lowest amounts of all combined forms of N to runoff load due to reduced runoff volume. The compost amended soil had the highest concentrations of dissolved phosphorus (DRP) and total phosphorus (TP), but had lowest total P loading due to high rates on infiltration and low runoff volumes. "An increase in the risk of nutrient transport to surface water due to an increase of C, N and P concentrations in runoff water from compost-amended soils be balanced by increased infiltration, porosity, and water-holding capacity that reduce runoff volume" (Evanylo et al., 2008). By the end of the experiment, soil P increased by 52 ppm in the high compost AC and BCF treatments. All treatments increased in soil test P at the 0.001 probability level, in the following order: CTL < LC <F<PL< LCF < BC < AC< BCF. The authors offer some warning against long term compost soil amendments; "Such a high soil P accumulation rate under continuous compost addition may result in increased risk of P transport from soil to surface water" (Evanylo et al., 2008).

Data limitations	Replicated plot research is capable of detecting the significant impacts of management on soil health outcomes. Due to the time period of the study, long term impacts of these practices were not evaluated. Subsurface phosphorus flux was not measured.
References	Evanylo, G., Sherony, C., Spargo, J., Starner, D., Brosius, M., & Haering, K. (2008). Soil and water environmental effects of fertilizer-, manure-, and compost-based fertility practices in an organic vegetable cropping system. *Agriculture, ecosystems & environment*, *127*(1-2), 50-58.

Soil Health Scenario #5a: Hayland with broadcast manure compared to incorporation with aerator

Scenario description	
Title of scenario	Hayland with broadcast manure compared to manure incorporation with aerator
Source of information	Long-term on-farm research in Vermont, results of which have been published in two articles: White, A., Faulkner, J. W., Conner, D., Barbieri, L., Adair, E. C., Niles, M. T., Mendez, V.E. & Twombly, C. R. (2021). Measuring the Supply of Ecosystem Services from Alternative Soil and Nutrient Management Practices: A Transdisciplinary, Field-Scale Approach. *Sustainability*, *13*(18), 10303. Twombly, C. R., Faulkner, J. W., & Hurley, S. E. (2021). The effects of soil aeration prior to dairy manure application on edge-of-field hydrology and nutrient fluxes in cold climate hayland agroecosystems. *Journal of Soil and Water Conservation*, *76*(1), 1-13.
Location and soil type	A farm in Shelburne, Vermont Vergennes clay, Covington silty clay, and Palatine silt loam at 3% and 2.7% slope
Land use and management history	Fields were in hay production for at least 10 years prior to the research study being set up.
Detailed description of management/treatments and study design	A field-scale paired watershed study was set up to evaluate the effects of using an aerator prior to manure application on mixed legume-grass hay fields in Vermont. Two fields with similar characteristics were chosen to be control and treatment fields and edge-of-field water quality monitoring stations were installed. From 2012-2014 the two fields were managed the same way to evaluate inherent differences in hydrologic characteristics among the two fields. Beginning in June 2014, a 4.42-meter-wide vertical-tine aerator was used before manure application in the treatment field. Water quality parameters were monitored through the duration of the study. Soil health was measured using the CASH test at the beginning and end of the study, in 2012 and 2018. Greenhouse gas emissions were monitored in years 2016-2018. Yield and economic data were also tracked through the duration of the study.
Time period of data collection	2012-2018
Measured soil health outcomes	
Summary of influence on soil health	Overall CASH soil health scores increased in both fields, but to a greater extent in the aerated field. Organic matter, aggregate stability and respiration increased in both fields, more so in the control field.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	Organic matter increased in both fields, by 1.6 percentage points in the aerated field, and 2 percentage points in the control field.
Bulk density	Not measured.

Aggregate stability	Aggregate stability increased in both fields, by an additional 17.4 percentage points in the control field and by an additional 25.8 percentage points in the aerated field.
N_2O & CO_2 emissions	Overall, N_2O was greater in the aerated field, and both fields were net carbon sinks. Average N_2O flux in the aerated field was 753 mg N_2O/m^2/year, equivalent to 2.24 MT CO_2e /hectare/year. In the control field flux was 596 mg N_2O/m^2/year, and 1.77 MT CO_2e /hectare/year. Average CO_2 flux in the aerated field was 663355 mg CO_2/m^2/year, equivalent to 6.63 MT CO_2e /hectare/year. In the control field flux was 692748 mg $C0_2/m^2$/year, and 6.98 MT CO_2e /hectare/year. Considering, N_2O emissions, CO_2 emissions and carbon sequestration together, both fields were net carbon sinks and the control field was a larger sink.
Soil biodiversity	Soil biodiversity was not measured. Respiration increased by 0.3 mg CO_2 in the aerated field and by 0.4 mg CO_2 in the control field. Active carbon increased by 68 ppm in the aerated field and by 40 ppm in the control field.
Additional Information	
Other data (yield, etc.)	No discernable trend in yields between the two fields was observed. The aerated field grossed $36 less than the control field. Aeration reduced concentrations of dissolved nutrient and suspended solids, but increased total runoff volumes, and thus had no significant impact on nutrient loads.
Data limitations	Data only shows comparison between two fields with clay soils over time, so should not be assumed to be representative of all fields.
References	White, A., Faulkner, J. W., Conner, D., Barbieri, L., Adair, E. C., Niles, M. T., Mendez, V.E. & Twombly, C. R. (2021). Measuring the Supply of Ecosystem Services from Alternative Soil and Nutrient Management Practices: A Transdisciplinary, Field-Scale Approach. *Sustainability*, *13*(18), 10303. Twombly, C. R., Faulkner, J. W., & Hurley, S. E. (2021). The effects of soil aeration prior to dairy manure application on edge-of-field hydrology and nutrient fluxes in cold climate hayland agroecosystems. *Journal of Soil and Water Conservation*, *76*(1), 1-13.

Soil Health Scenario #5b: Hayland with injected manure, with and without urease inhibitor

Scenario description	
Title of scenario	Hayland with different nitrogen sources (manure and synthetic urea) and application methods (manure injection and surface application)
Source of information	Brickman, S., Adair, E.C., Darby, H. (& maybe other coauthors). (Manuscript in preparation). Drivers of soil-borne greenhouse gas emissions from different nitrogen sources and manure application methods in a Northeast hayfield.
Location and soil type	Borderview Research Farm in Alburgh, VT . Soils were a mix of poorly drained Covington silty clay loam and well drained Nellis silt loam (Soil Survey Staff, 2017) with a texture class of silt loam.
Land use and management history	The experiment was conducted in a hayfield that had been unfertilized since 2006 and contained a mix of grasses (*Phalaris arundinacea, Poa pratensis, Frestuca pratensis, Agrostis stolonifera, Doctylis glomerata*), legumes (*Trifolium* sp.), and weeds (*Taraxacum officinale*).
Detailed description of management/treatments and study design	The trial occurred over two growing seasons from June 2020-November 2021, and treatments were arranged in a randomized complete block arrangement. Within each block, the plot treatments were the application of a commercial urease inhibitor, ContaiN MAX (AgXplore, Parma, MO), and control (no application of the inhibitor). Each plot was divided into four subplots with treatments of manure injection, surface manure application, synthetic fertilizer amendment, and control (no fertilization). We applied fertilizer and inhibitor treatments within a week after harvests in 2020 and 2021. Treatment application dates were 16 June 2020, 13 August 2020, 2 June 2021, and 30 July 2021. Liquid dairy cattle manure was applied at a rate of 42,092.7 L ha^{-1} using a tractor-drawn tank spreader (Kuhn) in the broadcast plots and a shallow-slot manure injector (Veenhuis Euroject 1200 grassland injector) in the injection plots. The injector disk cut slots 2.5-5 cm deep with 20 cm between each strip, and the shoe following the disk placed manure in the slot so that the manure extended from the slot bottom to the soil surface in strips that ran the length of each injection subplot. For the manure with inhibitor treatments, ContaiN MAX was mixed with the manure before application to achieve a target rate of 1.3 L ha^{-1}. We applied urea with and without inhibitor at a rate of 145.7 kg ha^{-1} using a variable rate drop spreader. Control without inhibitor subplots were watered without any fertilizer application, and control with inhibitor subplots were sprayed with ContaiN MAX (without fertilizer application). We harvested all subplots three times both years, but in 2020, yield and forage quality were only measured during the latter two harvests. Harvest occurred during mid to late boot stage for the first cut and was targeted for when the forages reached a height of 25-30 cm (10-12 inches) for subsequent cuts.
Time period of data collection	2 years, June 2020 – November 2021
Measured soil health outcomes	
Summary of influence on soil health	We did not find nitrogen source (manure or synthetic urea), manure application method (injection or broadcast), or inhibitor application to be important predictors of N_2O and CO_2 fluxes. Average daily N_2O emissions were generally low in our trial compared to those measured in manure injection and broadcast trials in annual

	corn systems (Dittmer et al., 2020; Duncan et al., 2017) but comparable to those measured in perennial forage systems (Rodhe et al., 2006; Sadeghpour et al., 2018). Because the trial was just two years, we did not expect to observe changes in soil carbon in response to treatment, and we only measured total carbon, total nitrogen, soil organic matter, and bulk density in control without inhibitor subplots.
Directionality and measured extent of impact on selected soil health indicators:	
Organic matter	Mean 8.7% organic matter at the study site
Bulk density	Mean 1.22 g cm^{-3} at the study site
Aggregate stability	Not measured
N_2O & CO_2 emissions	Rather than manure application method or nitrogen source, the primary drivers of N_2O and CO_2 emissions were related to environmental conditions – soil moisture or temperature – and nitrogen availability. Because the inhibitor did not measurably impact emissions, we describe treatment differences by fertilizer type and manure application method. Across all treatments, the mean daily flux rate for N_2O and CO_2 was 21.4 ± 49.3 g N_2O-N ha^{-1} d^{-1} and 45.7 ± 24.7 kg CO_2-C ha^{-1} d^{-1}, respectively. Daily N_2O fluxes ranged from 0-670.8 g N_2O-N ha^{-1} d^{-1} and CO_2 fluxes ranged from 0-164.5 kg CO_2-C ha^{-1} d^{-1}. The most important predictors of daily N_2O fluxes were soil moisture, CO_2 emissions, and NO_3-N concentration, with higher values of these variables predicting higher N_2O fluxes. The mean daily N_2O fluxes for manure injection, manure broadcast, synthetic fertilizer, and the control were 28.8 ± 52.0 g N_2O-N ha^{-1} d^{-1}, 30.8 ± 70.9 g N_2O-N ha^{-1} d^{-1}, 15.3 ± 33.3 g N_2O-N ha^{-1} d^{-1}, and 10.3 ± 22.3 g N_2O-N ha^{-1} d^{-1}, respectively. Similar to N_2O daily fluxes, abiotic variables drove CO_2 fluxes, but unlike for N_2O fluxes, soil temperature was the most important predictor, followed by days since treatment application, NH_4-N concentration, N_2O fluxes, and soil moisture. Daily CO_2 fluxes increased with temperature, with the lowest fluxes occurring at cooler soil temperatures in Oct-Nov and the highest in May-Sept, when soil temperatures averaged 8.9 ± 4.7 ºC and 18.6 ± 2.7 ºC, respectively. The mean daily CO_2 fluxes for manure injection, manure broadcast, synthetic fertilizer, and the control were 51.1 ± 28.7 kg CO_2-C ha^{-1} d^{-1}, 46.3 ± 26.4 kg CO_2-C ha^{-1} d^{-1}, 41.4 ± 21.4 kg CO_2-C ha^{-1} d^{-1}, and 44.2 ± 20.5 kg CO_2-C ha^{-1} d^{-1}, respectively.
Soil biodiversity	Not measured
Additional Information	
Other data (yield, etc.)	In both years, yields at each harvest after treatment application were higher for the manure and synthetic fertilizer treatments than the control but were similar across fertilizer type, inhibitor use, and manure application method. The manure treatments had similar mean yields to the synthetic fertilizer treatment in both years, although the maximum values for manure treatments were 1.6 times higher than those for synthetic fertilizer, suggesting that manure application can generate larger yields but is mostly comparable to synthetic fertilizer. When yields were measured in May 2021, before treatment application, both manure treatments had mean yields 1.6-2 times larger than those of synthetic fertilizer and the control, suggesting that while manure amendment mostly did not have an impact on yields within 5-7 weeks after application, it may have long-term effects on biomass production.

Data limitations	Soil moisture levels were low throughout much of the growing season during our trial, so treatment effects may be more pronounced and GHG fluxes may be higher in wetter conditions.
References	Dittmer, K. M., Darby, H. M., Goeschel, T. R., & Adair, E. C. (2020). Benefits and tradeoffs of reduced tillage and manure application methods in a Zea mays silage system. *Journal of Environmental Quality, 49*(5), 1236-1250. https://doi.org/https://doi.org/10.1002/jeq2.20125 Duncan, E. W., Dell, C. J., Kleinman, P. J. A., & Beegle, D. B. (2017). Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry. *Journal of Environmental Quality, 46*(1), 36-44. https://doi.org/10.2134/jeq2016.05.0171 Rodhe, L., Pell, M., & Yamulki, S. (2006). Nitrous oxide, methane and ammonia emissions following slurry spreading on grassland. *Soil Use and Management, 22*(3), 229-237. https://doi.org/10.1111/j.1475-2743.2006.00043.x Sadeghpour, A., Ketterings, Q. M., Vermeylen, F., Godwin, G. S., & Czymmek, K. J. (2018). Nitrous Oxide Emissions from Surface versus Injected Manure in Perennial Hay Crops. *Soil Science Society of America Journal, 82*(1), 156-166. https://doi.org/https://doi.org/10.2136/sssaj2017.06.0208

Table 1. Summary table of management scenarios and measured influence on soil health indicators. Red indicates negative outcomes, green indicates positive outcomes. Scenarios are intended to be illustrative and many have limited inference across other farms and fields.

Title of scenario	**Best Management Practice Corn (No-till and Cover Crop)**	**Corn hay rotation**	**Transition from annual cropping to rotational grazing**	**Restoring soil function with management-intensive grazing rotation**
Scenario number	1	2	3a	3b
Soil texture	Rocky silt loam	Silt loam	Clay loam	Clay & silty clay
Time period	3 years, 2017-2020	11 years, 2012 – 2021	2 years, 2017-2018	6 years, 2015 - 2021
Influence on organic matter (indicator of Climate regulation, Downstream flood risk mitigation, & Climate resilience)	Over three years the accumulated effects were a net increase of 0.3% organic matter more in the BMP treatment than the conventional treatment.	Corn-hay rotation had a net additional 0.25% to 1.22 % organic matter compared to continuous corn treatment.	No change in soil organic carbon was detected between years	Preliminary data shows an increase of soil organic matter across the farm.
Influence on bulk density (indicator of Climate regulation & Downstream flood risk mitigation)	Bulk density was not measured, but penetrometer data is used as a proxy. Penetrometer data in 2020 was not statistically significantly different among the treatments.	No significant difference observed between treatments for bulk density samples collected in 2021.	Bulk density increased between 2017-2018.	Not reported.
Influence on aggregate stability (Indicator of Downstream flood risk mitigation, Soil conservation & Climate resilience)	Over three years the accumulated effects were a net increase of 11.1% more in water stable aggregates in the BMP treatment than the conventional treatment.	Corn-hay rotation had a net additional 9.4% to 41.3 % aggregate stability compared to continuous corn treatment (significant to p=0.1).	No change in water stable aggregates between years	Not reported.
Influence on N2O & CO2 emissions (indicator of Climate regulation)	Not measured. NRCS Comet Planner estimates non-legume cover crops increase N2O emissions and no-till reduces N2O emissions. Considering emissions & sequestration together, Comet Planner estimates the combination of practices is a net carbon sink.	Not measured. However, NRCS Comet Planner estimates adding perennial crop rotation reduce nitrous oxide emissions.	Not measured. However, NRCS Comet Planner estimates the conversion to forage and biomass plantings would reduce nitrous oxide emissions.	Not measured. Not enough information exists to project the impact of rotational grazing on nitrous oxide emissions.
Influence on soil biodiversity (indicator of Biodiversity)	No measure of biodiversity was collected. However, indicators of biological activity were collected. Over three years there was a greater net increase in soil respiration in the BMP treatment than in the conventional treatment.	No measure of biodiversity was collected. However, indicators of biological activity were collected. Corn-hay rotation had an additional 0.489 to 0.623 CO2 g soil-1 respiration compared to continuous corn treatment (significant to p=0.1).	Increases in soil biological activity (β-glucosidase activity, microbial biomass carbon and potentially mineralizable N) were observed.	Not reported.

Table 2 continued. Summary table of management scenarios and measured influence on soil health indicators. Red indicates negative outcomes, green indicates positive outcomes. Scenarios are intended to be illustrative and many have limited inference across other farms and fields.

Title of scenario	**Vegetables with a cover crop rotation**	**Vegetable production with reduced tillage**	**Fertility practices in organic vegetable systems**	**Hayland with aerataor**	**Hayland with variable nitrogen sources, manure applications & inhibitor use**
Scenario number	4a	4b	4c	5a	5b
Soil texture	Silt loam	Silt loam	Silty clay loam	Clay	Silt loam
Time period	4 years, 2003 - 2007	4 years, 2003 - 2007	2 years, 2000-2002	6 years, 2012-2018	2 years, 2020 - 2021
Influence on organic matter (indicator of Climate regulation, Downstream flood risk mitigation, & Climate resilience)	At the end of the study organic matter content was higher by 0.2% in the soil building rotation.	No significant differences in organic matter were detected in this study.	High compost rate treatments increased organic carbon more than other treatments. Organic carbon did not differ significantly between low compost rate treatment and the controls.	Organic matter increased in both fields, but more so in the control field.	Not measured.
Influence on bulk density (indicator of Climate regulation & Downstream flood risk mitigation)	Bulk density was not measured, but penetrometer data is used as a proxy. Surface and subsurface hardness were higher in the soil building rotation than the continuous cropping plots at the end of the experiment.	Bulk density was not measured. Surface hardness was significantly higher in the no till than the other two tillage treatments in the soil building rotation ($p<.01$), and significantly higher in zone till than full till in the continuous rotation.	High compost rate treatments reduced bulk density notably within two seasons. Low compost rate applications decreased bulk density noticeably after 3 years.	Not measured.	Not measured.
Influence on aggregate stability (Indicator of Downstream flood risk mitigation, Soil conservation & Climate resilience)	At the end of the experiment, aggregate stability was 5.1% higher in the soil building treatment than in the continuous cropping treatment	Aggregate stability was significantly higher in the zone tillage treatment in continuous rotation. The no till treatment was significantly higher in the soil building rotation ($p<0.05$).	Not measured.	Aggregate stability increased in both fields, but more so in the control field.	Not measured.
Influence on N_2O & CO_2 emissions (indicator of Climate regulation)	Not measured. NRCS Comet Planner tool estimates that perennial crop rotations reduce nitrous oxide emissions.	Not measured. NRCS Comet Planner tool estimates that reduced and no-till decrease nitrous oxide emissions.	Not measured. NRCS Comet Planner estimates increased N2O emissions from manure and compost amendments. Considering emissions sequestration together, these practices are generally net carbon sinks.	N2O flux was greater in the aerated field, though both fields were net carbon sinks. Considering emissions and sequestration together, both fields were net carbon sinks, the control field was a larger sink.	No significant influences on CO2 or N2O emissions from from nitrogen sources, manure application method or the use of urease inhibitor.
Influence on soil biodiversity (indicator of Biodiversity)	Soil biodiversity was not measured but active carbon can be used as an indication of biological activity. At the end of the experiment active carbon level were similar, but slightly higher in the soil building rotation.	No indicator of biological diversity was monitored. The best indicator of biological activity used in this study was active carbon. Active carbon was significantly reduced in the no till treatment only in the continuous rotation.	Not measured.	Soil biodiversity was not measured. Respiration increased by 0.3 mg CO2 in the aerated field and by 0.4 mg CO2 in the control field. Active carbon increased by 68 ppm in the aerated field and by 40 ppm in the control field.	Not measured.

Appendix A. Comet Planner output reports with scenario practices

COMET-Planner Carbon Sequestration and Greenhouse Gas Estimation Report

Project Name: Corn PES soil health scenarios

State: Vermont

County: Washington

Date Created: 04/22/2022 04:46:13

Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*
(tonnes CO_2 equivalent per year)

NRCS Conservation Practices	Acres	Carbon Dioxide	Nitrous Oxide	Methane	Total CO_2-Equivalent
Conservation Crop Rotation (CPS 328) - Decrease Fallow Frequency or Add Perennial Crops to Rotations	100	21	1	N.E.**	22
Residue and Tillage Management - No-Till (CPS 329) - Intensive Till to No Till or Strip Till on Non-Irrigated Cropland	100	42	4	0	46
Cover Crop (CPS 340) - Add Non-Legume Seasonal Cover Crop (with 25% Fertilizer N Reduction) to Non-Irrigated Cropland	100	13	-1	0	12
Totals:	300	76	4	0	80

*Negative values indicate a loss of carbon or increased emissions of greenhouse gases
**Values were not estimated due to limited data on reductions of greenhouse gas emissions from this practice

For more information on how these estimates were generated, please visit www.comet-planner.com.

Figure 2. NRCS Comet Planner report of practices in the corn soil health scenarios reviewed in this report. Generated at http://comet-planner.com.

COMET-Planner Carbon Sequestration and Greenhouse Gas Estimation Report

Project Name: Pasture PES soil health scenarios

State: Vermont

County: Washington

Date Created: 04/22/2022 04:49:58

Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*
(tonnes CO_2 equivalent per year)

NRCS Conservation Practices	Acres	Carbon Dioxide	Nitrous Oxide	Methane	Total CO_2-Equivalent
Forage and Biomass Planting (CPS 512) - Conversion of Annual Cropland to Non-Irrigated Grass/Legume Forage/Biomass Crops	100	120	16	0	136
Prescribed Grazing (CPS 528) - Grazing Management to Improve Rangeland or Non-Irrigated Pasture Condition	100	1	1	0	2
Multiple Conservation Practices - Prescribed Grazing (CPS 528) Replace Synthetic N Fertilizer with Dairy Manure (CPS 590) on Managed Non-Irrigated Pasture	100	21	-5	0	16
Totals:	300	142	12	0	154

*Negative values indicate a loss of carbon or increased emissions of greenhouse gases
**Values were not estimated due to limited data on reductions of greenhouse gas emissions from this practice

For more information on how these estimates were generated, please visit www.comet-planner.com.

Figure 3. NRCS Comet Planner report of practices in the pasture soil health scenarios reviewed in this report. Generated at http://comet-planner.com.

COMET-Planner Carbon Sequestration and Greenhouse Gas Estimation Report

Project Name: Vegetable PES soil health scenarios

State: Vermont

County: Washington

Date Created: 04/22/2022 04:56:48

Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*
(tonnes CO_2 equivalent per year)

NRCS Conservation Practices	Acres	Carbon Dioxide	Nitrous Oxide	Methane	Total CO_2-Equivalent
Conservation Crop Rotation (CPS 328) - Decrease Fallow Frequency or Add Perennial Crops to Rotations	100	21	1	N.E.**	22
Residue and Tillage Management - No-Till (CPS 329) - Intensive Till to No Till or Strip Till on Non-Irrigated Cropland	100	42	4	0	46
Residue and Tillage Management - Reduced Till (CPS 345) - Intensive Till to Reduced Till on Non-Irrigated Cropland	100	15	1	0	16
Mulching (CPS 484) - Add Mulch to Croplands	100	32	0	N.E.**	32
Nutrient Management (CPS 590) - Improved N Fertilizer Management on Non-Irrigated Croplands - Reduce Fertilizer Application Rate by 15%	100	-2	0	0	-2
Nutrient Management (CPS 590) - Replace Synthetic N Fertilizer with Chicken Broiler Manure on Non-Irrigated Croplands	100	19	-15	0	4
Nutrient Management (CPS 590) - Replace Synthetic N Fertilizer with Compost (CN ratio 20) on Non-Irrigated Croplands	100	42	-9	0	33
Totals:	700	169	-18	0	151

Figure 4. NRCS Comet Planner report of practices in the vegetable soil health scenarios reviewed in this report. Generated at http://comet-planner.com.

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Results of the 2022 Vermont Farmer Conservation & Payment for Ecosystem Services Survey

Vermont Payment for Ecosystem Services Technical Research Report #3a

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group by

Alissa White

June 2022

Table of Contents

Acknowledgements

The development and circulation of this survey was coordinated by Nour El Naboulsi in his role as a UVM Research Assistant in the winter of 2022 with support from many people on the UVM research team, primarily Lindsey Ruhl, Alissa White, & Heather Darby. Lindsey Ruhl led development of the survey section on conservation implementation. Members of the Vermont Soil Health and Payment for Ecosystem Services Working Group were integral to developing and distributing the survey. Farmers and farmer groups across the state of Vermont contributed to refining the survey language and encouraging participation from farmers.

This survey was conducted with support from the Vermont Payment for Ecosystem Services Working Group via the Vermont Agency of Agriculture, Food & Markets, as well as funding from the Vermont Clean Water Initiative Program.

We'd like to acknowledge the farmers who helped develop the survey, the farmers who participated in the survey, the Vermont PES Working Group and the broader network in Vermont that helped get the word out about the survey. Thank you all!!

Recommended Citation

White, A. 2022. Results of the 2022 Vermont Farmer Conservation and Payment for Ecosystem Services Survey. Vermont Payment for Ecosystem Services Technical Research Report #3a. University of Vermont

Introduction

This survey was commissioned by the Vermont Soil Health and Payment for Ecosystem Services Working Group (VT PES Working Group) to gather farmer input on the development of payment for ecosystem services (PES) in Vermont for agriculture. In particular, the survey was intended to help set appropriate levels of compensation for participation in a soil health PES program, although additional information was gathered in the survey to inform the development of a new incentive program. The VT PES Working Group has explored the potential for a performance-based soil health PES program that would compensate farmers on the basis of environmental performance, as indicated through measurable soil health indicators. While much research-based and local knowledge can be leveraged to determine appropriate practice-based payments, information on setting adequate levels of payment for performance-based payment rates is sparse.

This survey report presents data which can be used to gauge the range of payment levels that should be offered by a new soil health PES program in Vermont. It also includes information about Vermont farmers' environmental knowledge and attitudes, program design preferences, opinions and motivations. In the development of the survey, we determined that direct questions about payment rates based on units of ecological outcomes or soil health metrics would not yield meaningful information in a survey format. Instead, we aimed to estimate minimum and preferred levels of compensation based on the time burden required to participate in a performance-based soil health. Accordingly, we asked farmers to estimate the amount of time it would take them to complete soil sampling and data reporting, and then we asked them for fair hourly rates for those activities. Follow-up interviews were proposed to generate more meaningful information about payment levels.

Methods

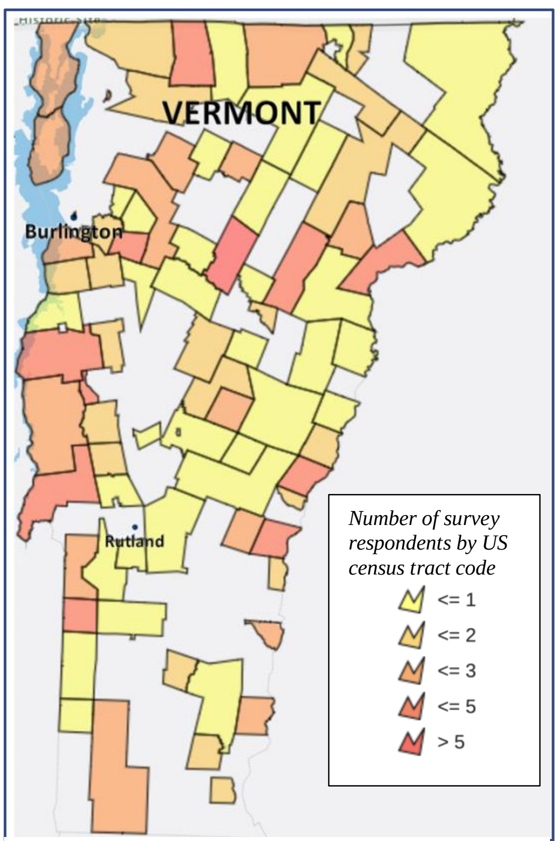


Figure 1. Geographic extent of survey responses.

The survey tool was developed over the course of four months, through an extensive input and revision process between October 2021 and February 2022. The survey questionnaire was edited and revised based on input from the Vermont Payment for Ecosystem Services Working Group, Vermont farmers, UVM researchers, staff from UVM extension, and non-profit advisors. A focus group with 12 farmers in January of 2022 provided discussion and input into the survey questionnaire. Five farmers trialed the draft survey and were interviewed in order to improve it. UVM IRB approved that the survey conformed with ethical standards for research with human subjects, and the survey was administered in an online format using the Qualtrics platform.

A total of 179 farmers in Vermont completed the survey from across the state (Figure 1). Outreach was conducted in multiple phases by the farmer networks and agricultural organizations represented on the VT PES Working Group. Farmers completed the survey online, and also over the phone with the assistance of UVM staff. The survey took an average of 28 minutes to complete.

Summary statistics were generated by a default report from Qualtrics on April 18th. Additional analysis and figures were generated in Excel and R in preparation of this report. No weighting procedure has been completed on this dataset.

Key Findings

- **99%** of Vermont farmers believe improvements in soil health have **benefits for the environment** off their farm, **95%** of Vermont farmers believe they should take additional steps beyond required practices to **protect soil health,** and **90%** of Vermont farmers believe they have a responsibility to **be part of climate solutions.**

- **94%** of Vermont farmers believe they have the **knowledge and technical skill to enhance soil health** on their farm, yet only **58%** have the **financial capacity** to do so.

- **92%** of farmers ranked **direct monetary payment** among their preferred form of compensation and **66%** of farmers ranked **tax incentives** as their preferred form of compensation. Debt forgiveness, technical assistance, crop insurance, health insurance, lower interest loans and retirement funds were ranked among the top three forms of compensation by **20%** to **28%** of respondents.

- **62%** of farmers prefer that application for new conservation incentive programs should be combined with existing conservation incentive program paperwork as much as possible to save time. **15%** believe their data privacy is more important and enrollment paperwork should not be shared between programs. **23%** had no preference.

- **46%** of farmers prefer the spatial basis for payments to be per acre, **40%** prefer whole farm scale.

- **Minimum level of compensation.**
    - The survey suggests an **average minimum level of compensation for the enrollment burden of $1000,** plus a performance-based payment, will incentivize applicants. Rates should be differentiated by farm size due to the difference in time required to collect data and report from larger farms.
    - **40%** of farmers felt they should be compensated for the **burden of enrollment** associated with a new PES program.
    - **80%** of farmers felt they should be compensated for the **burden of data collection, tracking and sharing** associated with a new PES program. Most farmers estimated it would take a few days to collect that data (20 hours), and the median hourly rate for this work should was $35 per hour. Based on this data, we estimate the lower end of compensation for enrollment and data reporting burden at an average of **$700 per farm**. Rates should be differentiated by farm size.
    - **82%** of farmers felt they should be compensated for the **burden of soil sampling** associated with a new PES program. Most farmers estimated it would take a 4 – 9 hours to collect basic soil samples from all of their fields. The mean hourly rate for this work should was $32 per hour. Based on this data, we estimate the lower end of compensation for soil sampling burden at **$288.**
    - **80%** of farmers felt they should be compensated on the basis of **soil health performance** associated with a new PES program.

- **Preferred level of compensation**
    - Among the 48 responses that suggested per acre compensation, the median rate was $100/acre, and the mean rate was **$206/acre.** The range of suggestions spanned from a minimum of $2/acre to a maximum of $3500/acre. Among the 12 respondents that suggested whole farm compensation levels, the mean level was $**5,000 per farm**. The range of suggestions spanned from a minimum of $50 per farm to a maximum of $50,000 per farm.

Section1. Farm Characteristics

Q1. How many acres do you farm?

Table 1. Size of respondent's' farm in acres.

Size of farm in acres	% of respondents
1-9	21.39%
10-49	19.79%
50-179	17.65%
180-499	28.34%
500-999	9.63%
1000-1999	1.60%
2000+	1.60%

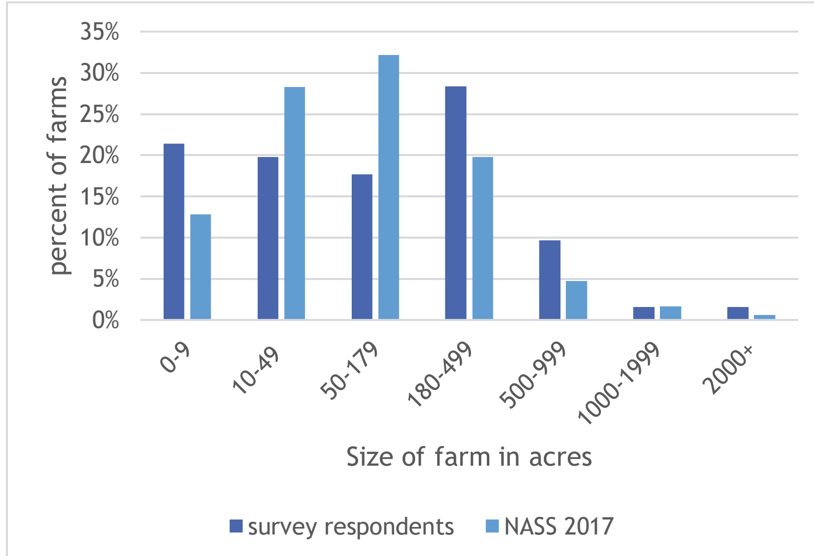


Figure 2. Comparison of our survey respondents with the NASS survey of Vermont farms in 2017.

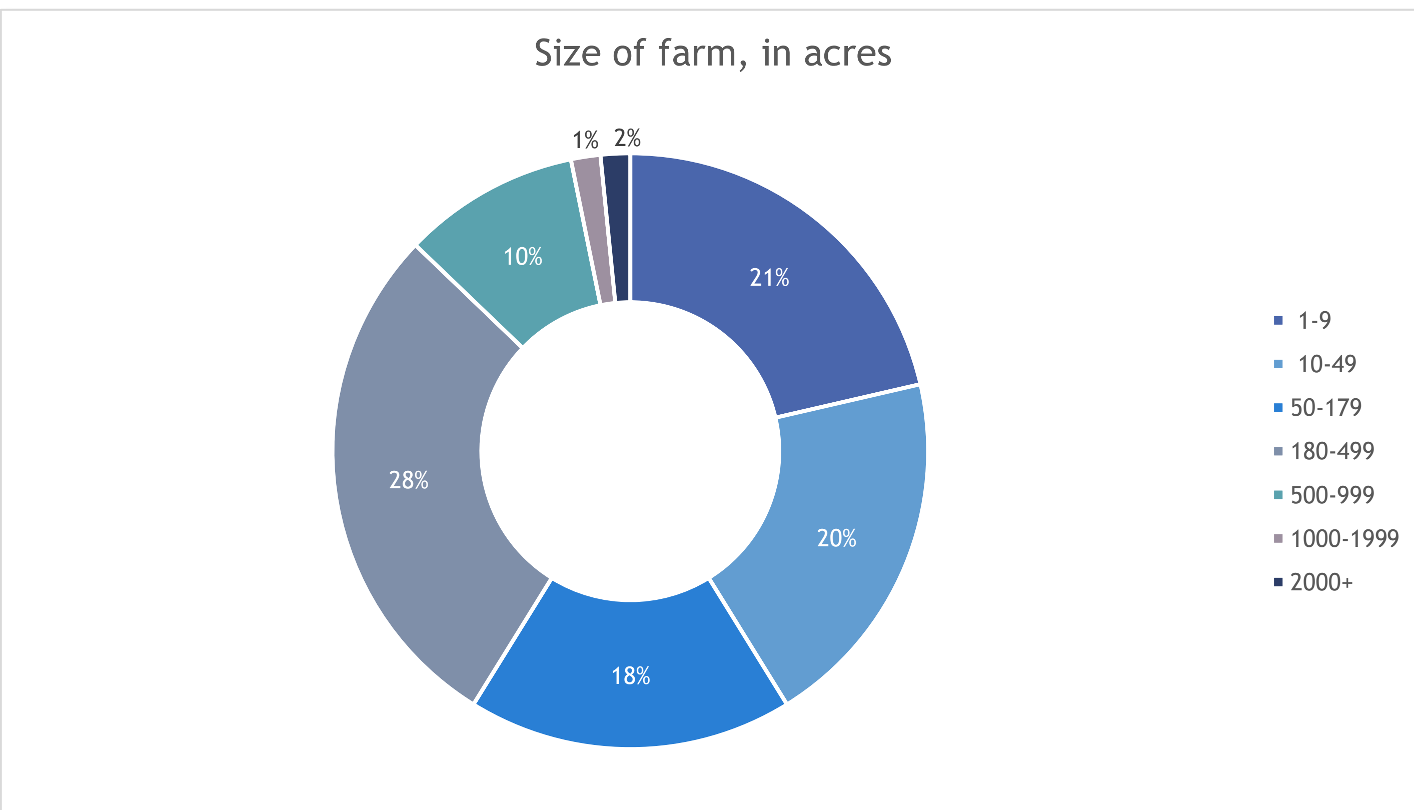


Figure 3. Size of respondent's farm in acres.

Q2. What are the main agricultural goods produced and sold from your farming operation?

Table 2. Agricultural good produced and sold from respondent's farm.

Agricultural products	% of respondents	# of respondents
Milk from cows	32.62%	61
Cattle and calves (beef, heifers, etc.)	19.79%	37
Poultry and eggs	21.39%	40
Hay	31.02%	58
Vegetables and/or berries	46.52%	87
Sheep/goats	13.37%	25
Hogs and pigs	10.70%	20
Maple	17.65%	33
Tree fruits/nuts	17.65%	33
Milk from sheep/goats	1.60%	3
Value-added products	30.48%	57

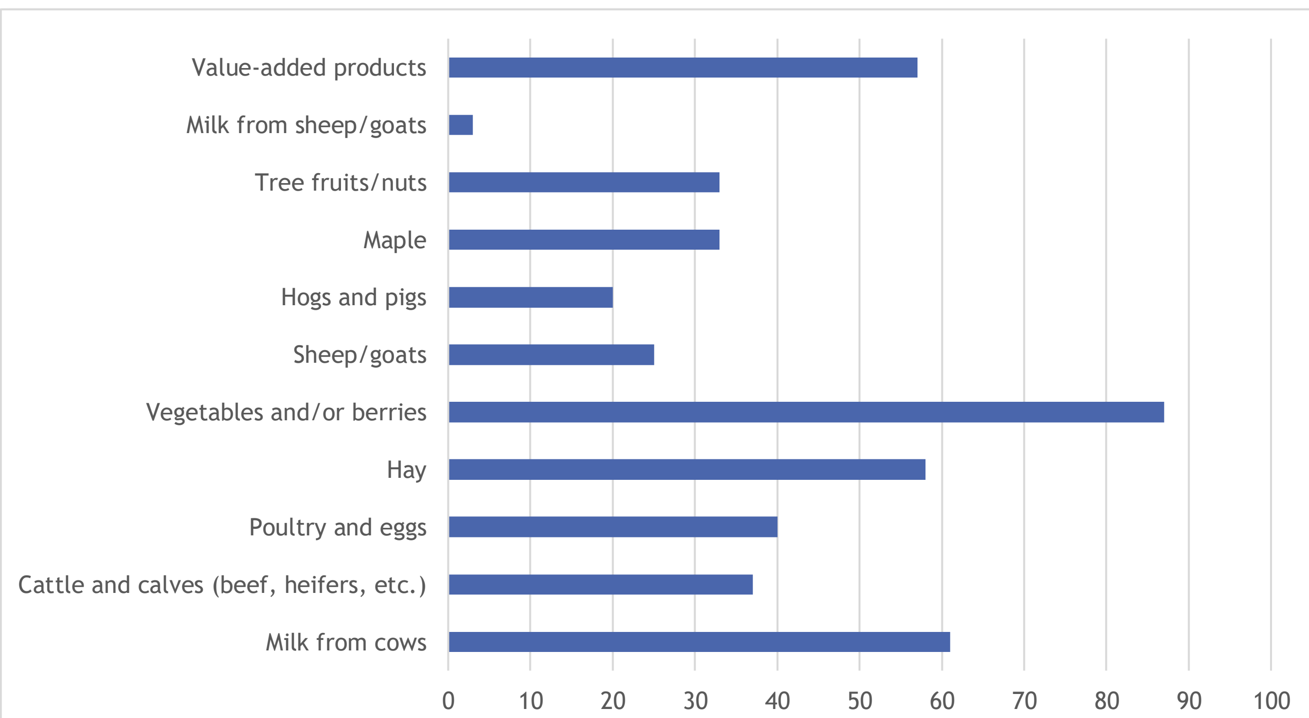


Figure 4. Agricultural good produced and sold from respondent's farm.

Q3. What is your gross annual farm income?

Table 3. Gross annual farm income among respondents.

Gross annual farm income	% of respondents
Less than $1,000	7.19%
$1,001 to $49,000	34.64%
$50,000 to $149,000	15.03%
$150,000 to $349,000	16.34%
$350,000- $999,999	14.38%
$1,000,000-$4,999,999	11.76%
More than $5,000,000	0.65%

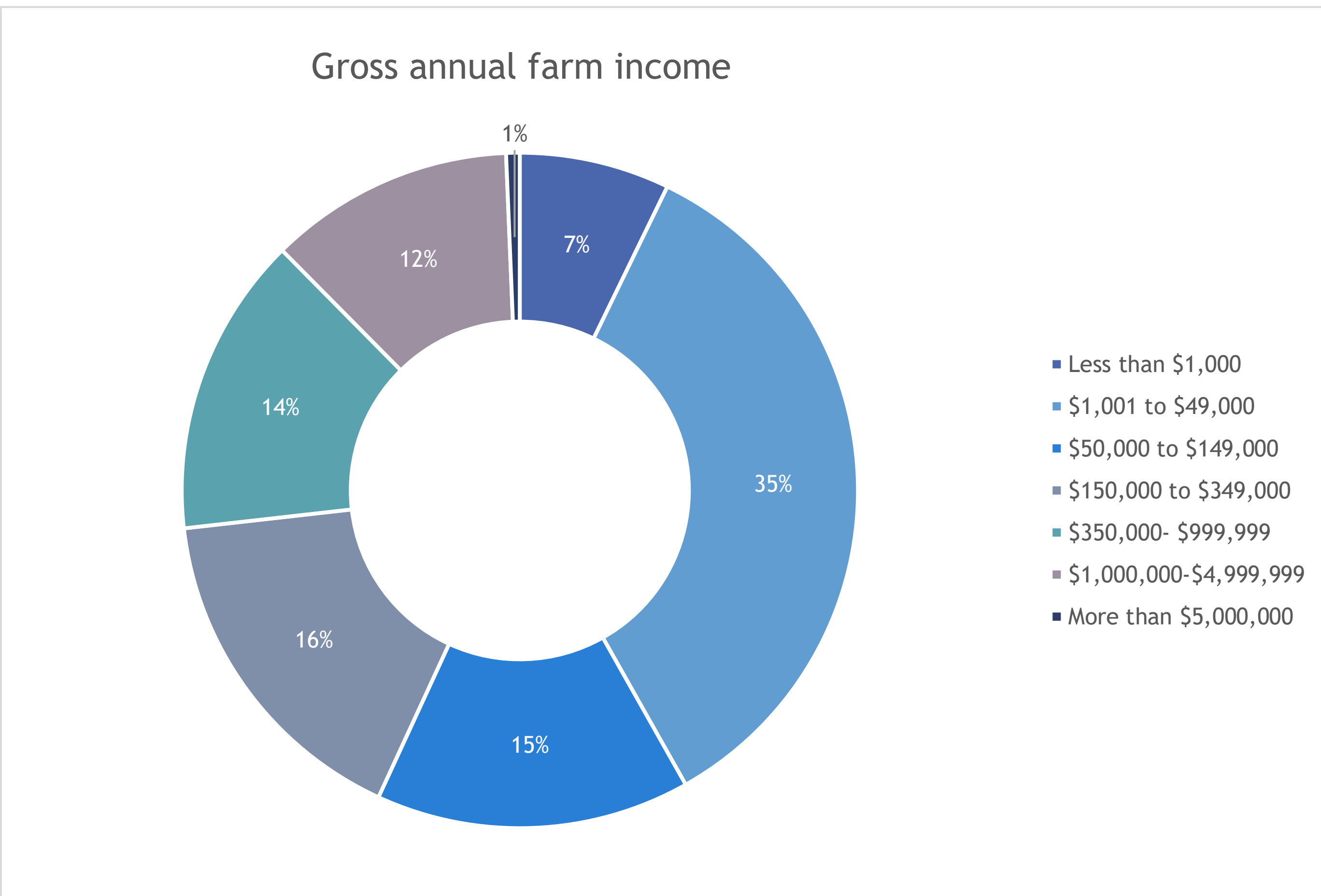


Figure 5. Gross annual farm income among respondents.

Q4. What is your farm ownership model?

Table 4. Farm ownership models of respondents.

Answer	% of respondents
Family	63.40%
Individual	22.22%
Community	1.31%
Collective/collaborative	2.61%
Other (please specify):	10.46%

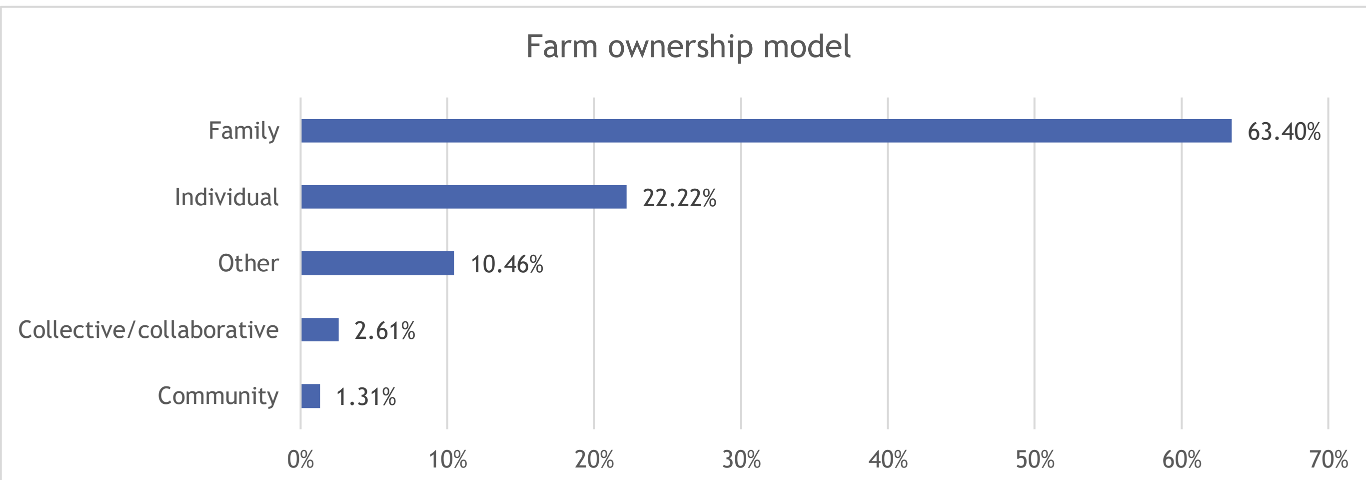


Figure 6. Farm ownership models of respondents.

Q5. Is any part of your farm under organic certification?

Table 5. Percent of respondents who have organic certification.

Organic certification	% of respondents
Yes	45.16%
No	54.84%

Q6. How would you describe the most common soil texture on your farm?

Table 6. Dominant soil texture on respondent's farm.

Dominant soil texture	% of respondents
Sand	3.76%
Silt	3.23%
Loam	23.66%
Clay	17.20%
Clay-loam	18.82%
Silty-loam	16.67%
Sandy-loam	16.67%

Q7. What bodies of water do you have on your property?

Table 7. Bodies of water on respondent's property.

Bodies of water	% of respondents
No bodies of water on property	10%
Rivers	22%
Streams	53%
Intermittent streams	48%
Vernal pools	25%
Ponds	44%

Section 2. Ecosystem Services

Survey respondents were given the following introductory language for this section of the survey on ecosystem services:

> The following sections will gauge your opinions on ecosystem services and associated management scenarios. Agriculture is a fundamental part of our culture and landscapes. Here, natural functions and cycles play an important role. Human life and well-being depend, for example, on the availability and occurrence of fertile soils, clean water and stable natural cycles that offer protection from natural hazards or space for recreation in nature. These natural services are also referred to as "ecosystem services" and are a central topic of current nature conservation measures and agri-environment programs. The ecosystem services we are focusing on in this study can be changed for better or worse based on farming practices. Some ecosystem services like fertile soils may directly benefit you as a farmer as well as the surrounding environment. Others like downstream water quality for drinking and swimming may benefit your community members but not as directly benefit your farm. Others still like climate regulation may benefit society on a global scale.
>
> In this study, we are interested in your perspective on ecosystem services specifically related to soil health. Some measurable qualities of soil are useful indicators of ecosystem services, and can be changed by the way farmland is managed. The following section will gauge your opinions about ecosystem services and the soil health indicators associated with ecosystem services.

Q8. Prior to this survey, were you familiar with the term ecosystem services?

Table 8. Familiarity with the term 'ecosystem services' prior to the survey.

Familiarity with ecosystem services	% of respondents	Count
Yes	58.89%	106
No	15.56%	28
Somewhat	25.56%	46

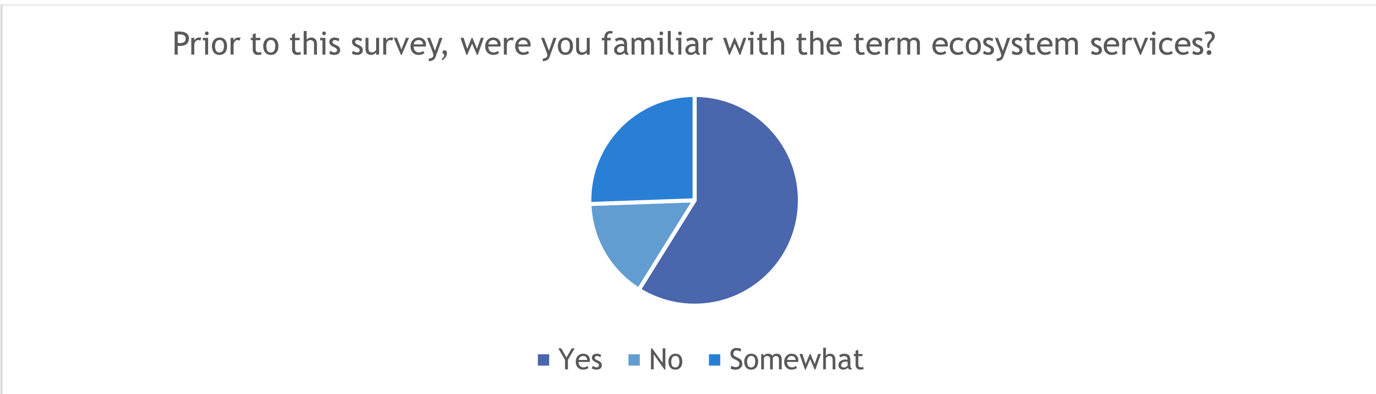


Figure 7. Percent of respondents familiarity with the term 'ecosystem services' prior to the survey.

Q9. Prior to this survey, were you familiar with the connection between your farming practices and ecosystem services?

Table 9. Familiarity with the connection between farming practices and ecosystem services.

Familiar with the connection between farming practices and ecosystem services	% of respondents	Count
Yes	62.78%	113
No	7.78%	14
Somewhat	29.44%	53

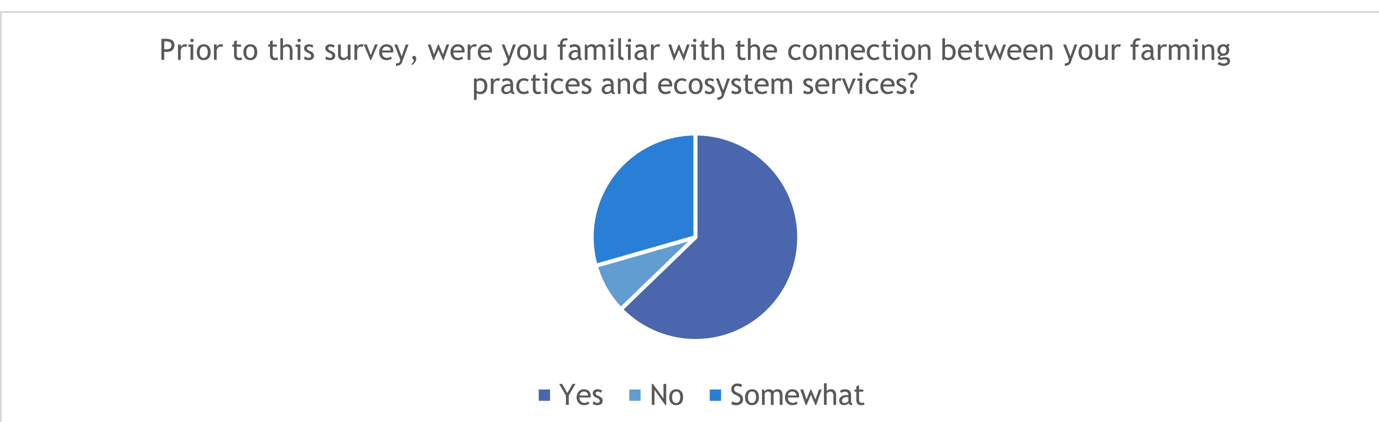


Figure 8. Percent of respondents familiar with the connection between farming practices and ecosystem services.

Q10. Please rank these five ecosystem services based on which are most important to you, with 1 being the most important and 5 being the least important.

Table 10. Ranked importance of selected ecosystem services to farmers.

Ecosystem Service	Rank 1 *Most important*	2	3	4	5 *Least important*
Climate regulation *Ecosystems regulate the global climate by storing greenhouse gases, preventing their release into the atmosphere.*	17.88%	11.17%	13.97%	23.46%	33.52%
Soil conservation *Ecosystems protect the topmost layer of soil from erosion and prevent reduced fertility caused by over usage, acidification, and salinization.*	39.44%	24.44%	18.33%	13.89%	3.89%
Downstream flood risk mitigation *Ecosystems slow down and store rainwater while protecting land from erosion, preventing floods.*	6.74%	11.80%	14.61%	22.47%	44.38%
Soil biodiversity *Ecosystems provide a biologically diverse mix of microscopic organisms, promoting fertile soil and enhanced plant growth.*	29.44%	31.67%	24.44%	11.11%	3.33%
Climate resilience *Ecosystems absorb stresses and maintain function in the face of external pressures, and adapt for future climate change impacts.*	25.70%	20.11%	24.02%	20.11%	10.06%

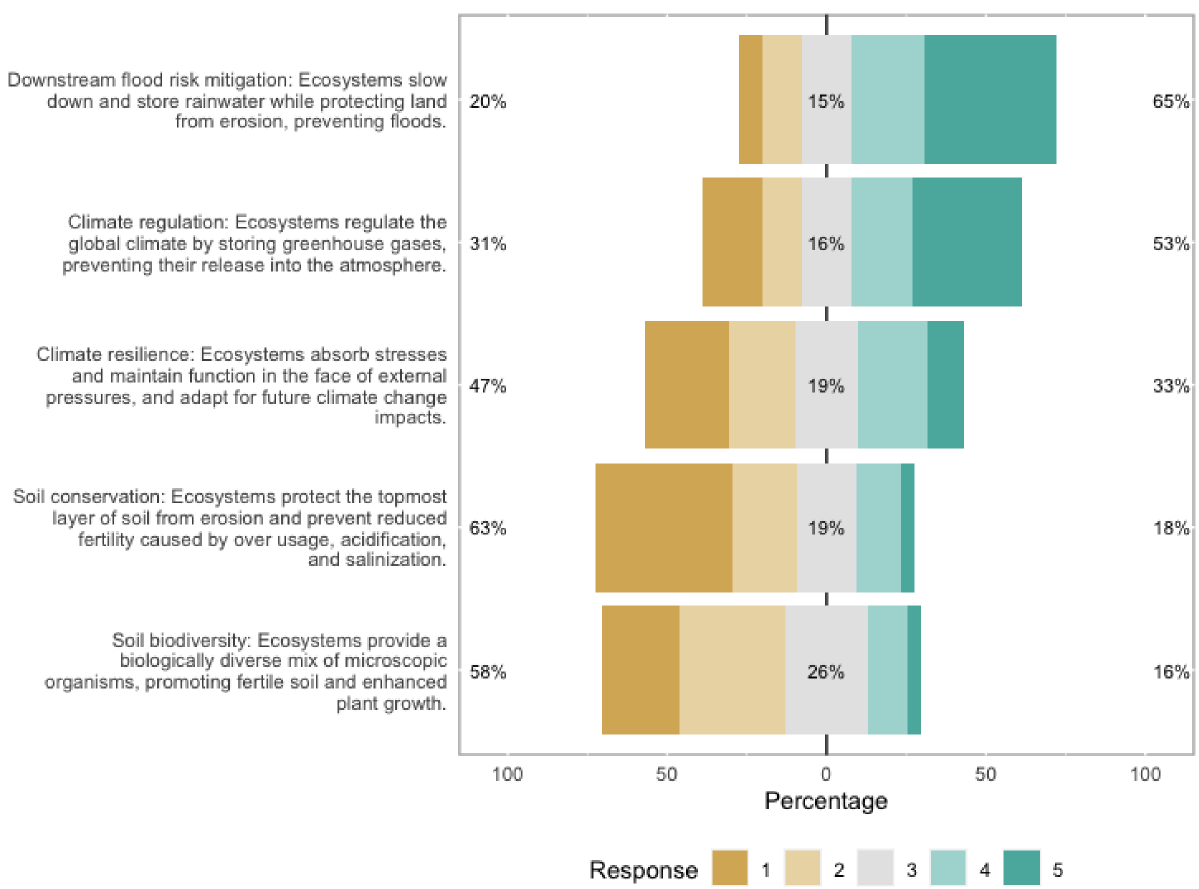


Figure 9. Ranked importance of selected ecosystem services to farmers.

Rationale for ranking of ecosystem services importance

Soil biodiversity and Soil conservation were ranked as most the important ecosystem services to farmers who took the survey. Downstream flood risk mitigation ranked lowest. Survey respondents were invited to describe their ranking in an open-ended question. Many farmers described the ranking process as being challenging because they are all important. For example, "It's hard to rank since they're all so vital to our community. "

Many farmers described their rationale through the relationships that these ecosystem services have with each other. Soil biodiversity and conservation were described as foundation that would allow, "the rest to fall into place." Soil is considered the basis to climate regulation provisioning, and as having a strong influence on water. For example, one farmer stated, "*they are all important, but it starts with living soil,"* and another said, *"Can't have any of the other functions if you don't have soil."*

Many farmers also highlighted their perceptions of relative risk, control and resilience capacity, as driving their ranking. For example, one farmer concerned with on-farm resilience said, "*my choice to rank climate resilience as the most important reflects the concern I have for the effects of extreme weather events and the external pressures associated with a changing climate on both our ability to continue successfully cropping land and making a living as well the quality of life and work of everyone in our community."* In some cases the perception of risks and impacts being less direct or immediate, or more diffuse, were the reason that some ecosystem services were ranked lower. As one farmer put it, *"My ranking prioritized the biggest risks to our farm's ability to sustain our quality of life, placing lesser priority on negative effects that are more diffuse, such as downstream flood risk mitigation and climate regulation. Still, I care very much about those ecosystem services that have a more diffuse effect on the broader community."*

Q11. Which of the following ecosystem services do you already consider when making management decisions on your farm?

Table 11. Percent of farmers who consider select ecosystem services when making management decisions.

Answer	% of respondents	Count
None of the above	2%	4
Climate regulation	43%	71
Flood mitigation	50%	84
Climate resilience	62%	104
Soil biodiversity	95%	159
Soil conservation	99%	165

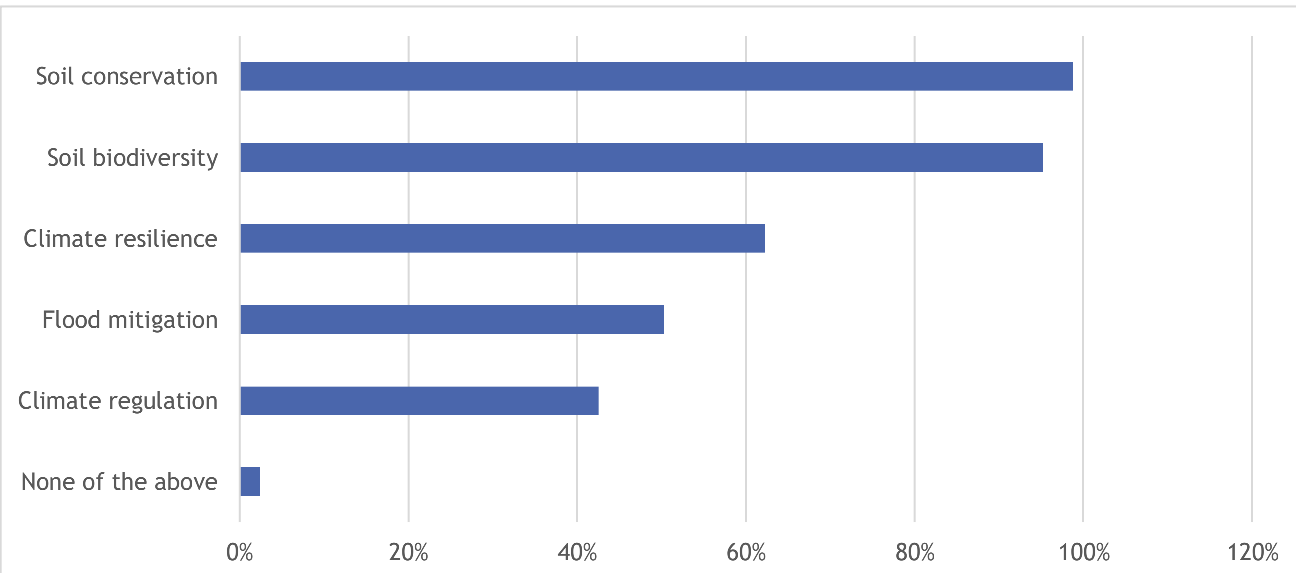


Figure 10. Ecosystem services considered by farmers when making management decisions.

Q12. Are there any other ecosystem services that you believe should be prioritized by agricultural programs and policy for Vermont farms?

Table 12. Additional ecosystem services that farmers believe should be prioritized by agricultural programs & policy for Vermont farms.

Answer	% of respondents	Count
Water quality	90%	150
Food production	77%	128
Pollination	75%	125
Wildlife biodiversity	73%	122
Timber production	40%	66
Recreation	29%	49
Tourism	28%	46
Spiritual wellbeing	21%	35
Other	10%	17
None	2%	4

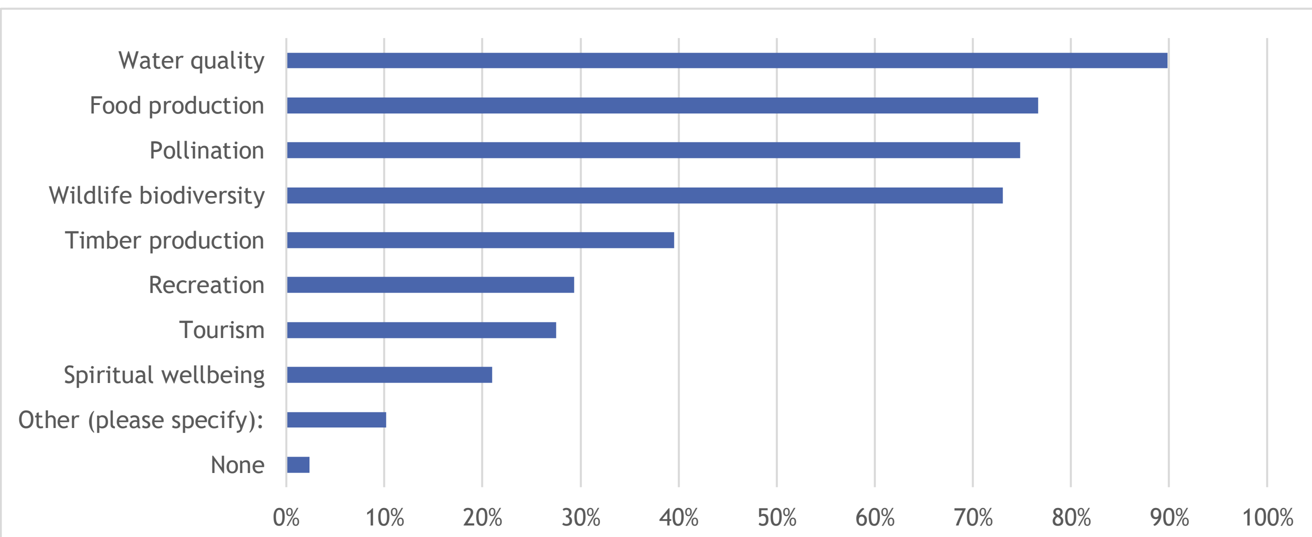


Figure 11. Additional ecosystem services that farmers believe should be prioritized by agricultural programs & policy for Vermont farms.

Section 3. Compensation & program elements

In this section of the survey, farmers were asked questions that could be used to inform the design and compensation structure of a performance-based soil health incentive program. Topics explored in this section include:

- preferred forms of compensation
- experience and knowledge of soil health testing & indicators
- preferred spatial basis for payment structure (field or farm scale)
- program elements that should be considered in setting compensation levels
- the amount of time farmers may spend on data reporting and soil sampling in a soil health PES
- hourly rates to use as a basis for setting compensation levels
- open-ended questions about preferred compensation and concerns

Survey respondents were given the following introductory language for this section of the survey on compensation:

> " The state of Vermont is interested in trying to compensate farmers for the ecosystem services that their farms provide. Again, the ecosystem services of particular interest are climate regulation, climate resilience, soil conservation, soil biodiversity, and flood risk mitigation. These ecosystem services can be influenced by the health, quality, and processes of soil, also known as soil health indicators. Soil health indicators are a key tool in measuring levels of ecosystem services. A few examples of soil health indicators are organic matter, bulk density, aggregate stability, and emission levels of carbon dioxide (CO_2) and nitrous oxide (N_2O).
>
> The goal of this program is ultimately to compensate farmers for managing their land in such a way that enhances these measurable soil health indicators, and as a result positively influences the related ecosystem services. Our hope is that this payment strategy, which would pay for results, will complement existing conservation programs such as the Environmental Quality Incentives Program (EQIP), which pays for practices like cover cropping and conservation tillage. One method we are exploring for measuring the soil health indicators and determining payment for ecosystem services would be based on more advanced soil testing and reporting, as well as other information about your farm. Within the following section, some of the questions will try to gauge the time and effort required by you to perform these tasks, what a fair rate of pay would be to perform these tasks, and whether or not you would prefer someone else (i.e. a trusted 3rd party) to perform these tasks. "

Forms of compensation

Survey respondents were asked to rank the top three forms of payment or compensation they would accept for increasing or sustaining soil health. 159 respondents answered this question.

The most popular forms of compensation were direct monetary payment and tax incentives. 92% of farmers ranked direct monetary payment among their preferred form of compensation and 66% of farmers ranks tax incentives as their preferred form of compensation. Debt forgiveness, technical assistance, crop insurance, health insurance, lower interest loans and retirement funds were ranked in the top three by 20% to 28% of respondents. 9% of respondents ranked 'other' as an option and their responses identified grants for equipment and supplies such as seeds and fencing such as irrigation, as well as soil and water testing as preferred forms of compensation. One response questioned the need for compensation, and one response identified that being left alone by AAFM and Extension unless requested by the farmer would be a preferred form of compensation.

Q15. Please rank the top three forms of payment or compensation you would accept for increasing or sustaining soil health.

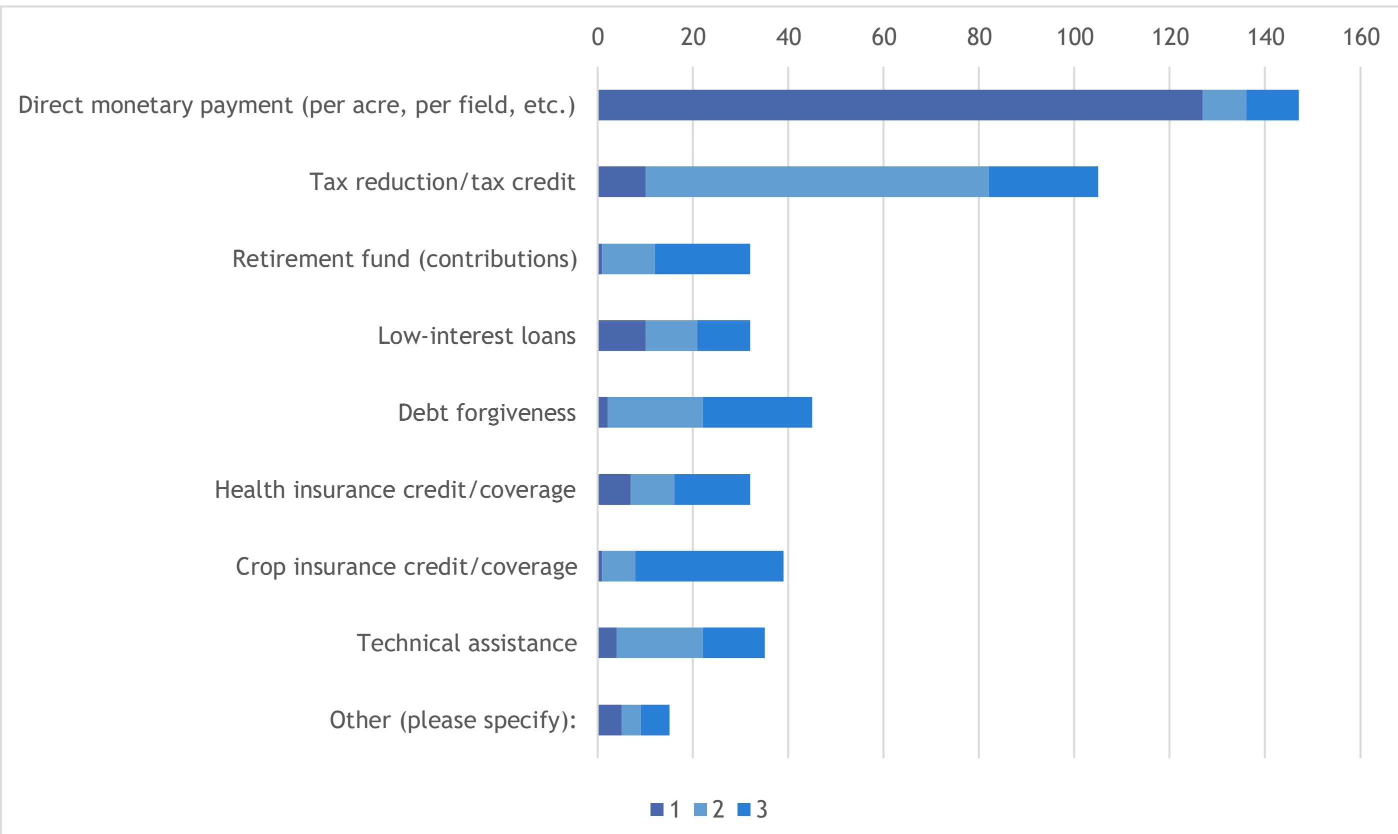


Figure 12. Top three preferred forms of compensation among Vermont farmers for a soil health payment for ecosystem services program, ranked 1 through 3.

Table 13. Preferred forms of compensation among Vermont farmers for a soil health payment for ecosystem services program, and their top three rankings.

Form of compensation	Total occurrences	Rank		
		1	2	3
Direct monetary payment (per acre, per field, etc.)	147	127	9	11
Tax reduction/tax credit	105	10	72	23
Retirement fund (contributions)	32	1	11	20
Low-interest loans	32	10	11	11
Debt forgiveness	45	2	20	23
Health insurance credit/coverage	32	7	9	16
Crop insurance credit/coverage	39	1	7	31
Technical assistance	35	4	18	13
Other	15	5	4	6

In addition to the multiple choice options, respondents were also give the opportunity to enter in additional ideas. These additional responses included:

- *Why do we have to be compensated to do the right thing?*
- *To be left alone by AAFM and AgEx unless involvement is requested.*
- *Special grant funding*
- *Equipment grants*
- *I feel direct monetary payment is primarily what I'm interested in. Farms already have tax incentives - some farms lease land and don't really directly benefit from that. different people and farms have different degrees of debt, not all farms have crop insurance, health insurance credit is not necessarily a benefit to everyone. Direct payments allow people to choose how best to spend the value they are creating.*
- *Grants for supplies, i.e. cover crop seed, fencing and water for rotational grazing. Testing, monitoring*
- *In kind payments: e.g. cover crop seed & seeding, conservation boundary and climate resilience plantings, energy conservation investments, etc.*
- *free soil and water testing.*
- *Direct payment to the vendor to repair/fix*
- *Compensation for soil testing (esp solvita/ woods end))*
- *Lower Property Taxes*
- *Marketing/sales assistance*
- *Someone come to farm to do the work*
- *Grants to improve*

Q13. Have you done soil health testing beyond your routine or required soil tests?

Table 14. Experience with advanced soil health testing among respondents.

Answer	% of respondents
Yes	45.51%
No	50.30%
Unsure	4.19%

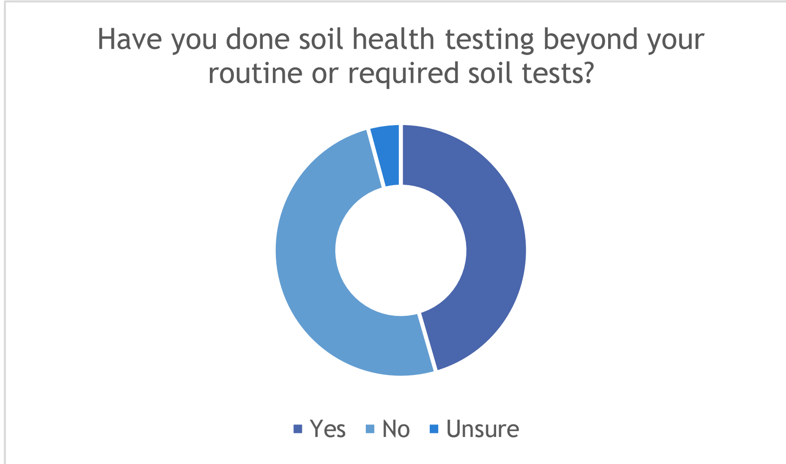


Figure 13. Experience with advanced soil health testing among respondents.

Q14. Are you familiar with any of these soil health indicators?

Table 15. Respondent's familiarity with selected soil health indicators.

Soil health indicator	% of respondents	Count
Organic matter	95.21%	159
Bulk density	44.91%	75
Aggregate stability	43.71%	73
CO2/N2O emissions off soil	34.73%	58
None of the above	3.59%	6

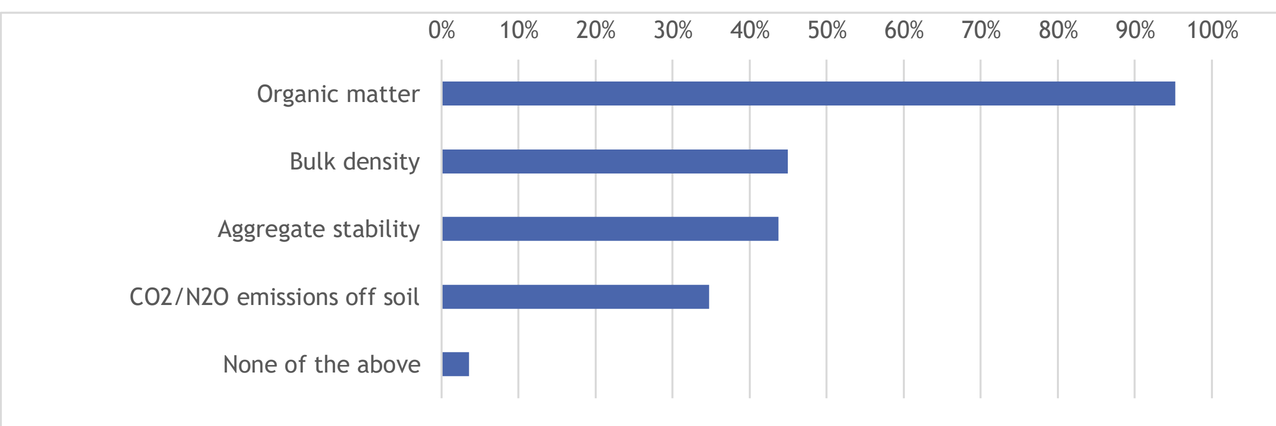


Figure 14. Percent of respondents familiar with selected soil health indicators.

Q16. If you were to be given a direct monetary payment for increasing or sustaining soil health, what form should this take?

Table 16. Preferred spatial basis for direct monetary payments.

Preferred spatial basis for payments	% of respondents
Per acre	46.11%
Whole farm payment	39.52%
Per field	2.99%
Other	11.38%

Comments about this question often suggested that a per acre payment rate be combined with different tiers. Many comments also suggested that payment be based on either the impact on ecosystem services, or the effort and cost of practice to the farm.

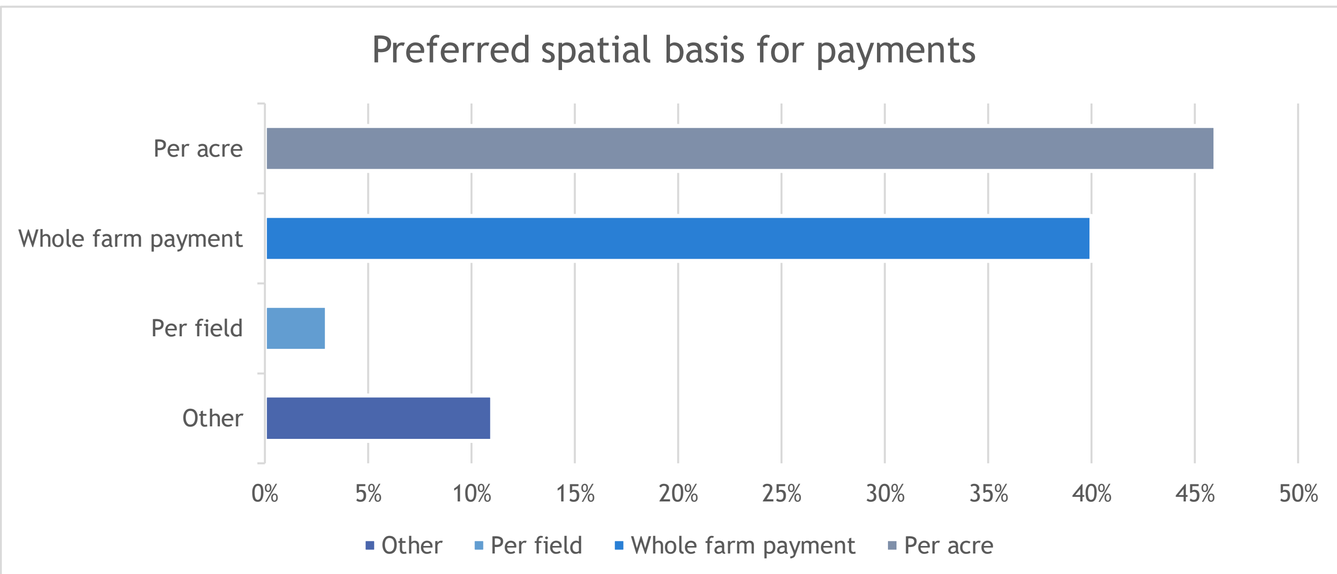


Figure 15. Percent of respondents who prefer selected spatial basis for direct monetary payments.

Q25. Privacy or efficiency. Which of the following is most important to you?

Table 17. Farmer preferences for either data privacy or reduced program paperwork through overlap with other programs.

Statement choices	% of respondents
The application for new conservation incentive programs should be combined with existing conservation incentive program paperwork as much as possible to save me time.	62.28%
My data privacy is important and enrollment paperwork should not be shared between programs.	14.97%
Neither is more important to me	22.75%

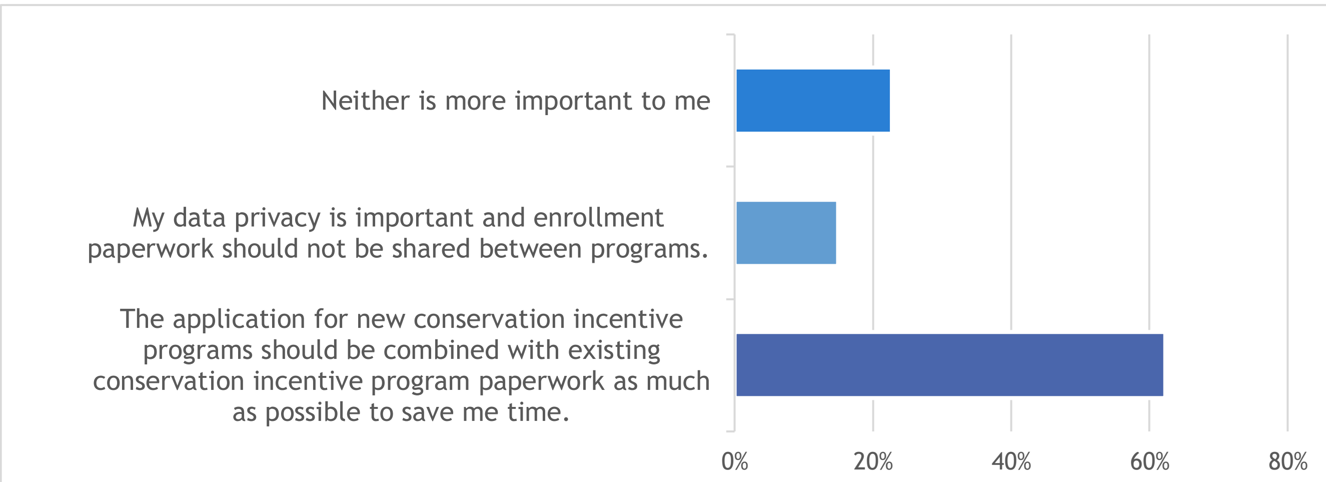


Figure 16. Farmer preferences for either data privacy or reduced program paperwork through overlap with other programs.

Q26. Do you think that technical assistance/education for farmers would be a necessary component of the program? (including application and other paperwork, soil testing, and data reporting)

Table 18. Need for technical assistance and education for farmers in a soil health PES program.

Answer	% of respondents	Count
Yes	78.44%	131
No	2.99%	5
Unsure	18.56%	31

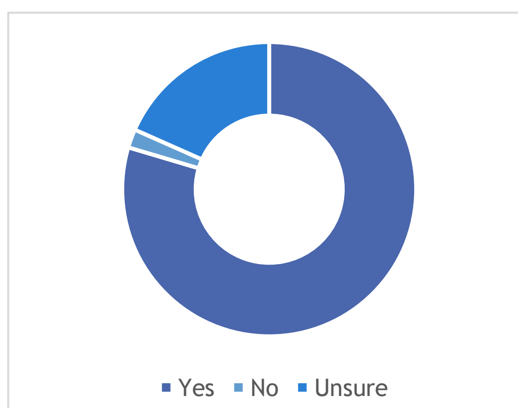


Figure 17. Need for technical assistance and education for farmers in a soil health PES program.

Q17. Would you allow a 3rd party to conduct the advanced soil measurements on your farm to participate in a program?

Table 19. Acceptance of third party organization to conduct advanced soil health tests on farms.

Answer	% of respondents
Yes	88.02%
No	1.20%
Unsure	10.78%

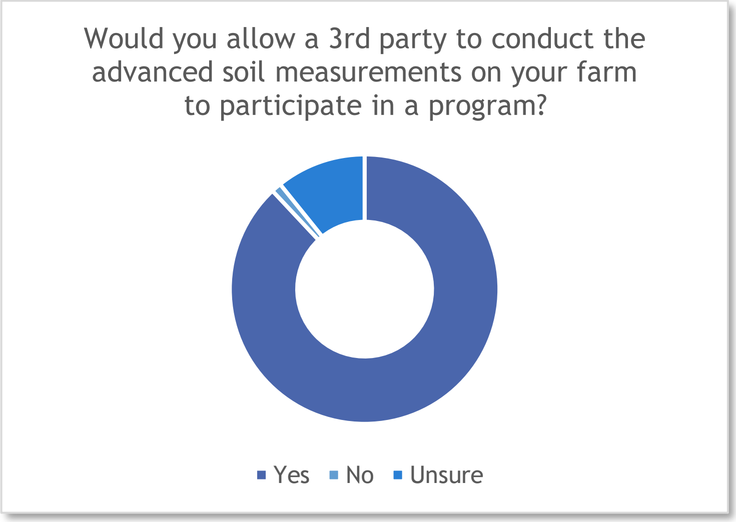


Figure 18. Acceptance of third party organization to conduct advanced soil health tests on farms.

Q18. Would you prefer to receive technical assistance so that you may eventually conduct these soil measurements yourself?

Table 20. Percent of farms who would prefer training in order to conduct measurements themselves.

Answer	%
Yes	52.69%
No	9.58%
Unsure	37.72%

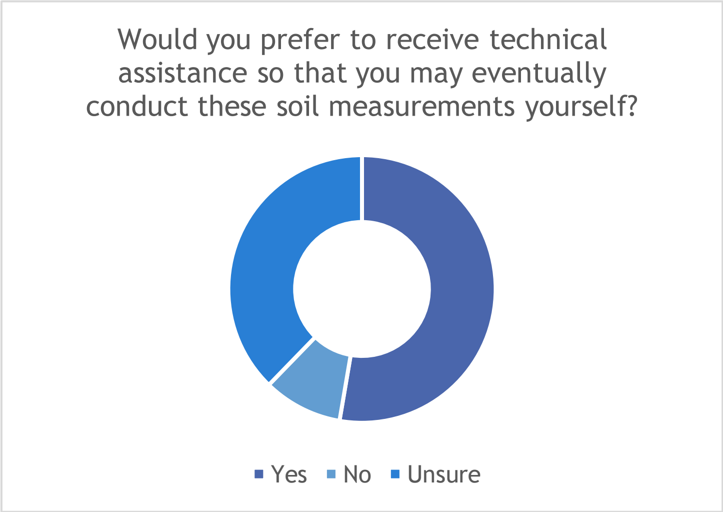


Figure 19. Percent of farms who would prefer training in order to conduct measurements themselves.

Q19. Which aspects of the program should you be compensated for?

Table 21. Aspects of program that farmers believe they should be compensated for.

Program element	% of respondents
Application and enrollment	40 %
Field sampling including basic and advanced soil measurements	82 %
Data collection, tracking, and sharing	80 %
Soil health outcomes/performance	80 %

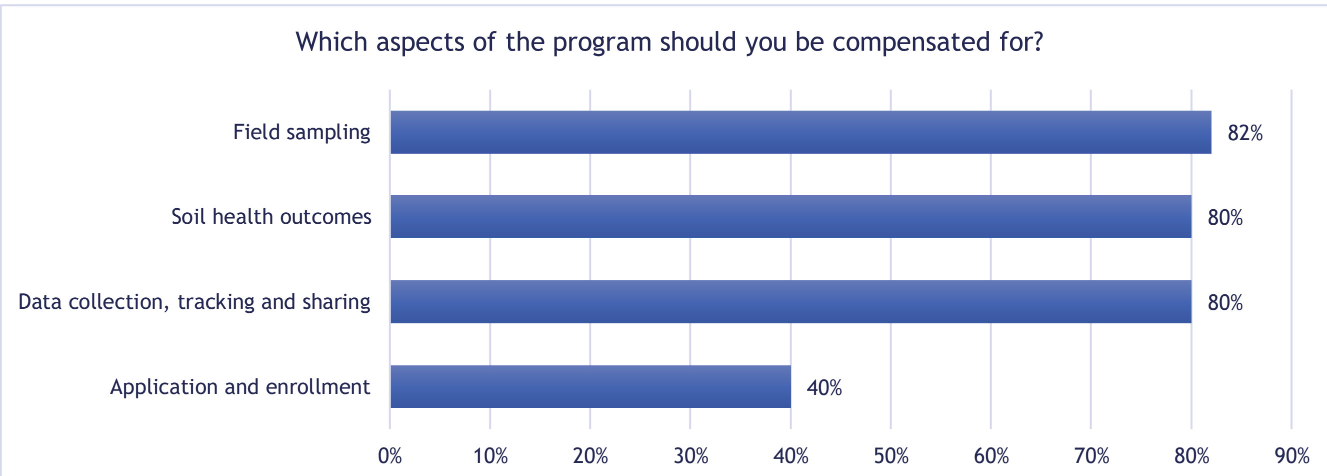


Figure 20. Aspects of program that farmers believe they should be compensated for.

Q20. Approximately how much time do you think it would take you to collect data on your management practices, conservation strategies, soil test results and other areas of your farm operation and report it to a new PES program?

Table 22. Estimated time farms would spend to collect and report management and soil data.

Data collection and reporting time	% of respondents	Count
Half a day or less	17.37%	29
A whole day	30.54%	51
A few days	40.12%	67
A week or more	11.98%	20

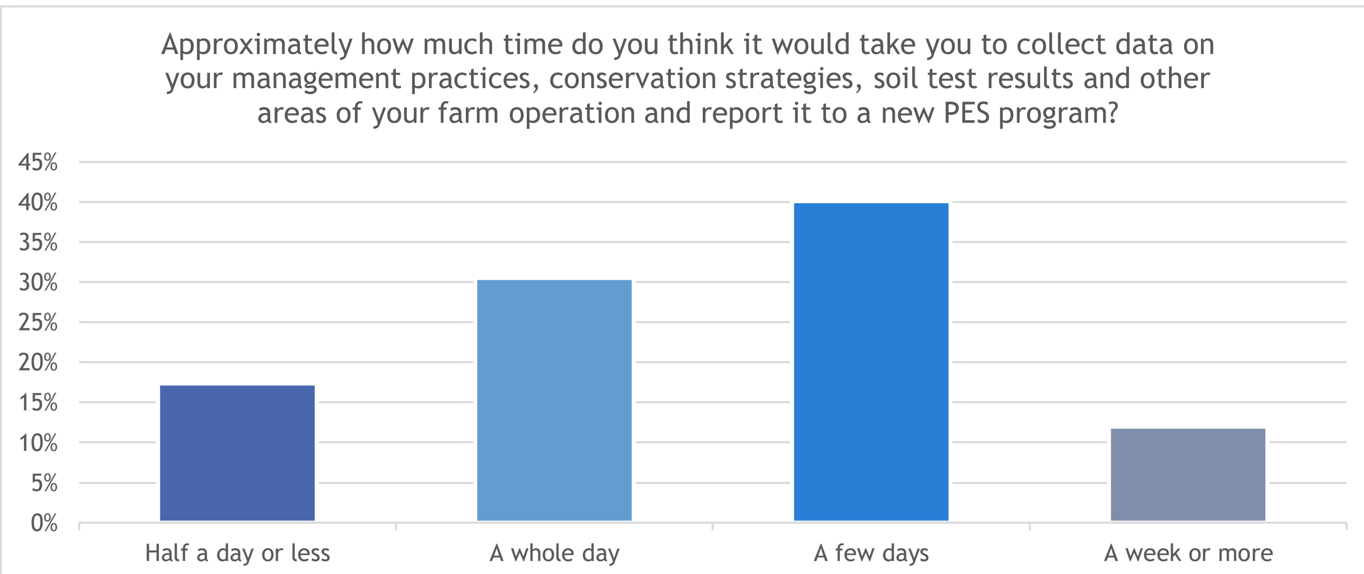


Figure 21. Estimated time farms would spend to collect and report management and soil data.

Q21. How many total hours do you think it would take you to collect a basic soil sample from each field on your farm?

Table 23. Estimated **hours to collect basic soil samples** from each field on the farm.

Acres	Min	Median	Mean	Max	Standard deviation
1-9	0.5	2	2.38	10	2
10-49	1	4	4.91	20	4.24
50-179	1	4	6.64	30	6.72
180-499	1	6	11.75	100	18.17
500-999	2	20	19.67	54	15.11
1000-1999	3	16	13	20	8.89
2000+	4	15	33.5	100	44.82
All farms	**0.5**	**4**	**8.71**	**100**	**13.96**

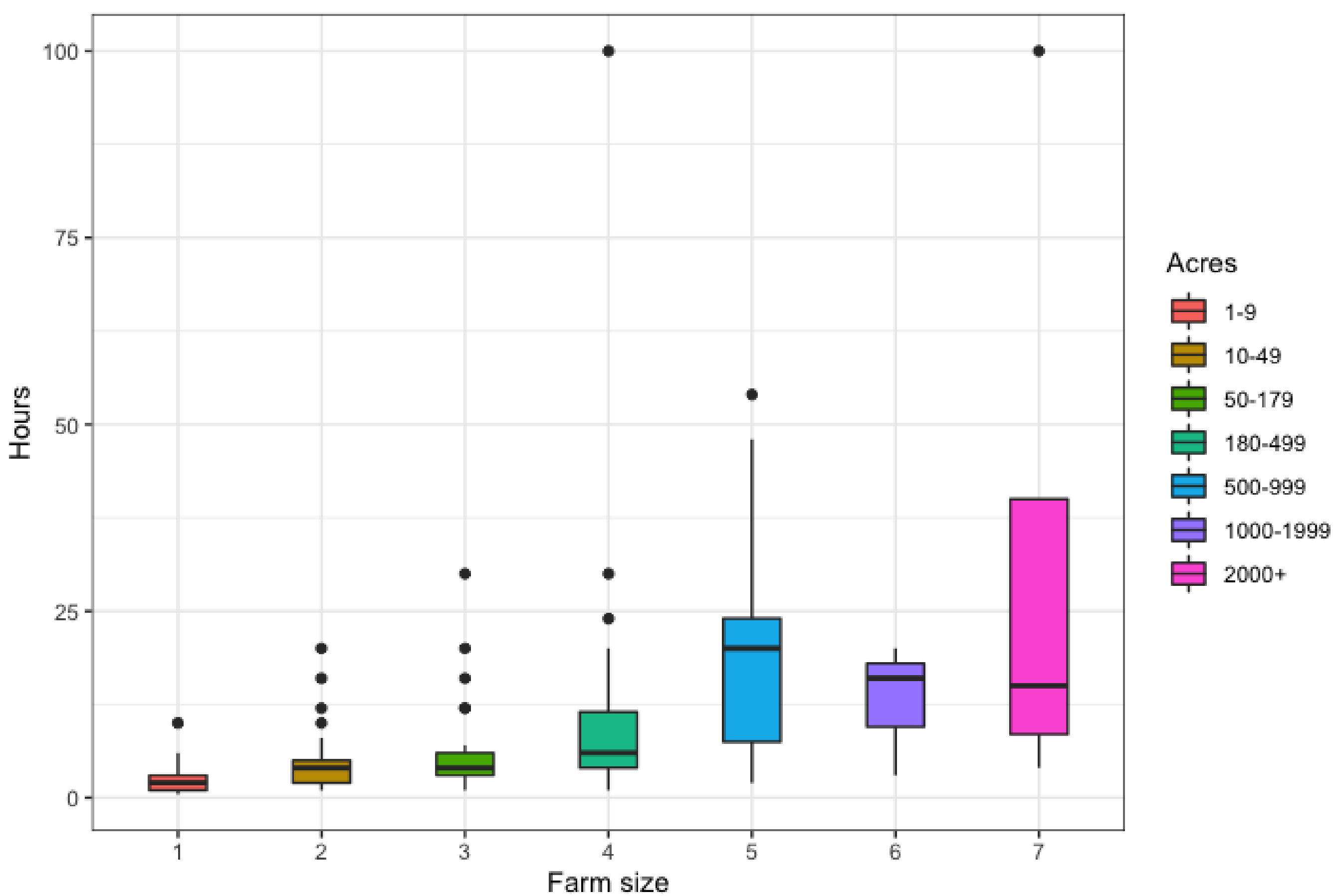


Figure 22. Estimated **hours to collect basic soil samples** on entire farm, by farm size.

Q22. If a program required you to share basic soil testing results and management practices for each field every year, what is the hourly rate you believe you should be paid for completing data entry? Please type your response in "per hour" format.

Table 24. Hourly compensation for **reporting data** on basic soil testing and management for each field.

Acres	Min	Median	Mean	Max	Standard deviation
1-9	10	25	33.09	100	23.22
10-49	0	25	32.14	100	20.42
50-179	2	25	37.78	250	45.04
180-499	2	25	41.88	300	51.44
500-999	0	25	26.94	60	16.38
1000-1999	20	25	40.00	75	30.41
2000+	20	40	47.50	90	30.96
All farms	**0**	**25**	**35.42**	**300**	**34.64**

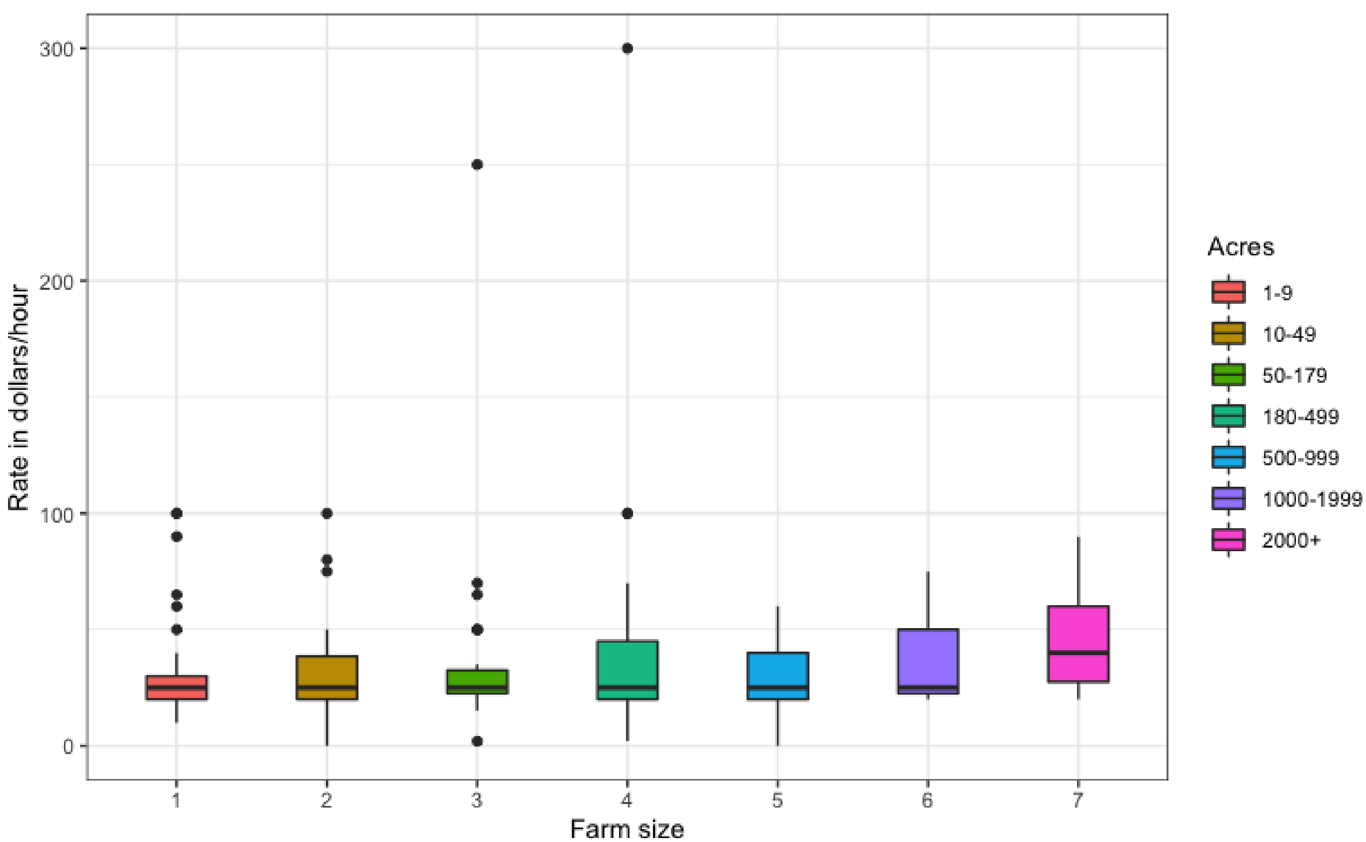


Figure 23. Hourly compensation for **reporting data** on basic soil testing and management for each field, by farm size.

Q23. If a program required you to conduct basic soil sampling on your farm, what is the hourly rate you should be paid for doing that work?

Table 25. Hourly compensation in dollars per hour for conducting **basic soil testing**, by farm size.

Acres	Min	Median	Mean	Max	Standard deviation
1-9	5	25	30.09	100	20.36
10-49	0	25	32.20	100	21.06
50-179	2	25	32.78	100	20.19
180-499	1	25	34.27	120	23.91
500-999	0	25	26.00	60	15.00
1000-1999	20	25	40.00	75	30.41
2000+	20	40	47.50	90	30.96
All farms	**0**	**25**	**32.14**	**120**	**21.16**

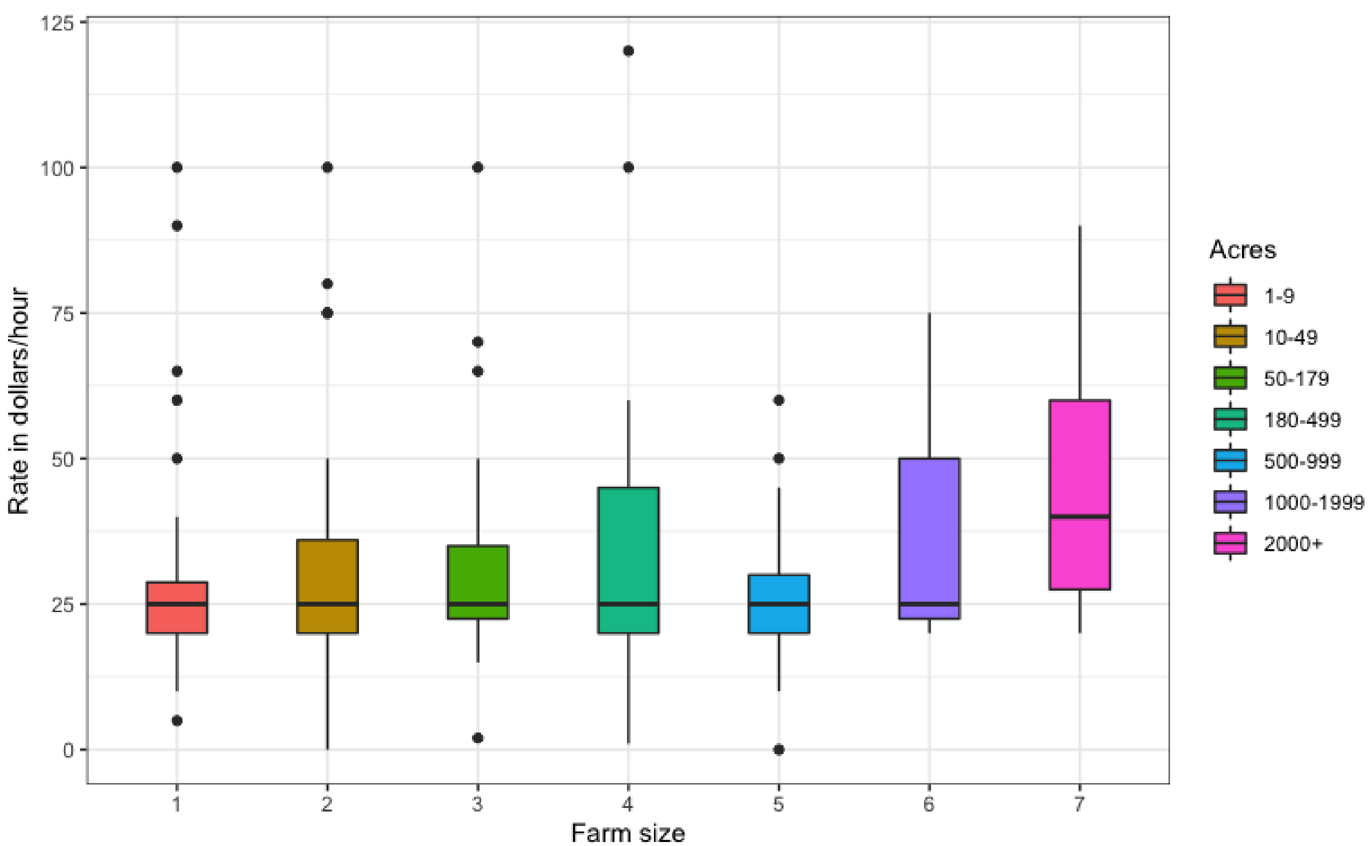


Figure 24. Hourly compensation in dollars per hour for conducting **basic soil testing**, by farm size.

Q24. If a program required you to conduct advanced soil testing (aggregate stability, bulk density, etc.) what is the hourly rate you should be paid for doing that work? Please type your response in "per hour" format.

Table 26. Hourly compensation in dollars per hour for conducting **advanced soil testing**, by farm size.

Acres	Min	Median	Mean	Max	Standard deviation
1-9	15	25	33.41	100	19.77
10-49	0	30	38.91	100	27.78
50-179	5	30	40.70	200	35.85
180-499	1	25	38.03	100	24.52
500-999	0	25	32.06	60	16.49
1000-1999	20	35	43.33	75	28.43
2000+	20	40	47.50	90	30.96
All farms	**0**	**30**	**37.37**	**200**	**25.98**

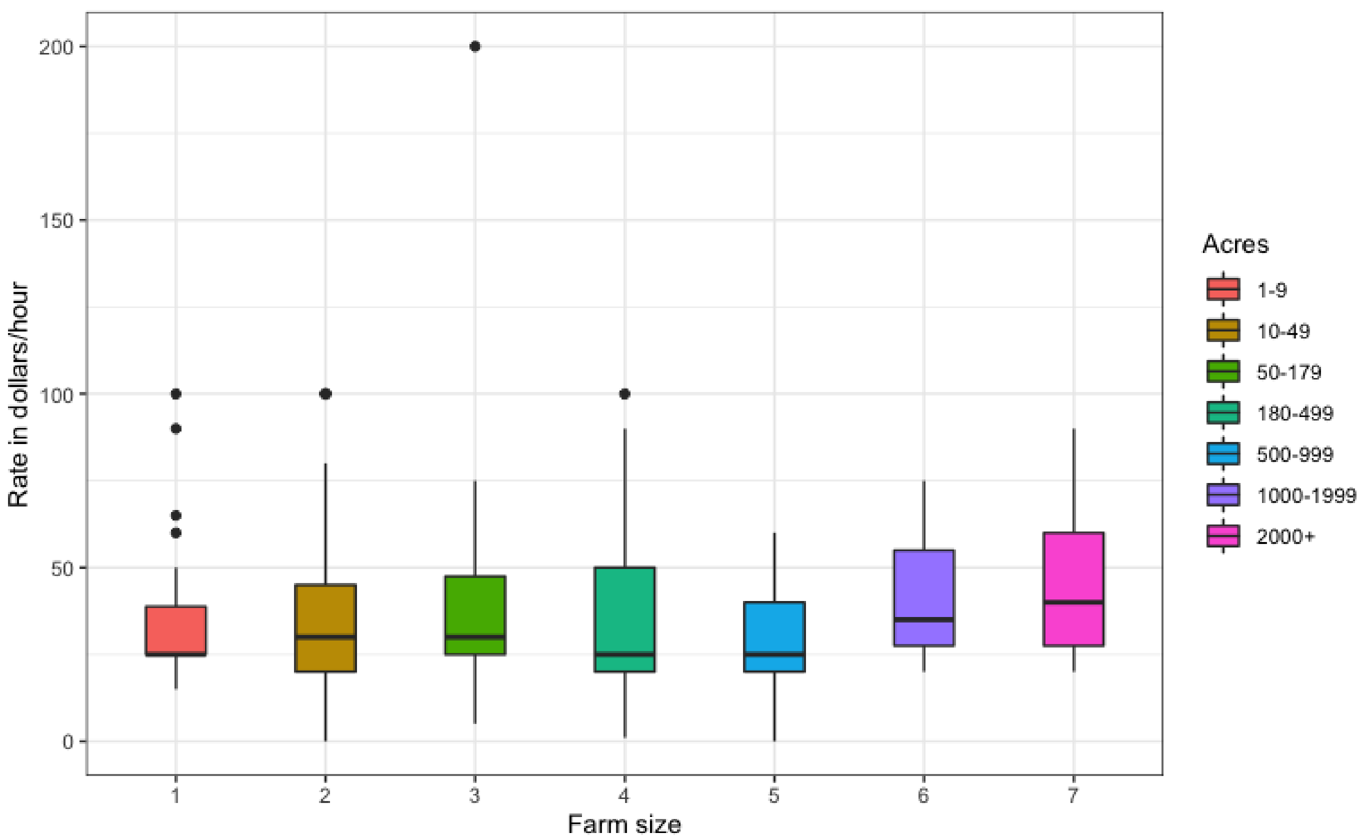


Figure 25. Hourly compensation in dollars per hour for conducting **advanced soil testing**, by farm size.

Q27. If a program compensated you based on how your soil test results compared to soil health threshold goals set by the program, how much do you believe you should be compensated for meeting those goals? Please type your answer in the box below and make sure to include units such as "per acre", "per field", etc. We understand this is a complex question with many factors.

Table 27. Suggested forms of fair compensation for meeting soil health threshold goals set by a soil health program.

Type of answer	Number of respondents
Per acre	48
Whole farm	12
Based on ecological outcome performance	14
Cost of practice	17
No payment	6
Per field	6
Based on cost of sampling	1

Among the 48 responses that suggested per acre compensation, the median rate was $100/acre, and the mean rate was $206/acre. The range of suggestions spanned from a minimum of $2/acre to a maximum of $3500/acre. Among the 12 respondents that suggested whole farm compensation levels, the median level was $900 per farm, and the mean level was $5,000 per farm. The range of suggestions spanned from a minimum of $50 per farm to a maximum of $50,000 per farm.

Q28. Please share your greatest concern(s) with entering a new conservation program

Farmers greatest concerns with entering a new conservation program were overwhelming that the burdens of paperwork and time not be worth it. Additional concerns include the following:

- complex paperwork and documentation
- the amount of time burden enrolling in new program would take away from crucial farm tasks
- data privacy & lack of confidentiality
- payments not being sufficient to justify participation
- the amount of time data collection would require
- reduced agency & loss of decision-making ability
- that the program actually result in meaningful benefits to environment, land, farmers and communities
- greenwashing & additionality
- commodification of data
- commodification of ecosystem services and subsequent undervaluation of them
- that the program would be too complex
- that the program would not be holistic, accurate or ambitious enough
- that wealthy landowners benefit more than farmers
- than agricultural land prices increase out of reach for farmers
- short term yield reductions
- new regulations or mandatory enrollment
- land use restrictions & red tape
- inconsistent funding for the program
- changes after enrollment
- inadequate technical assistance
- that previous stewardship be rewarded
- incompatibility or redundancy with emerging carbon market & existing programs
- consistent interpretation of measures by different audiences
- usability of information
- fairness
- long term nature of good management & soil health outcomes

Figure 26. Word cloud of farmers' concerns with a new conservation incentive program.

Section 4. Conservation Practices and Current Incentive Programs

Q32. What conservation practices do you implement on your farm?

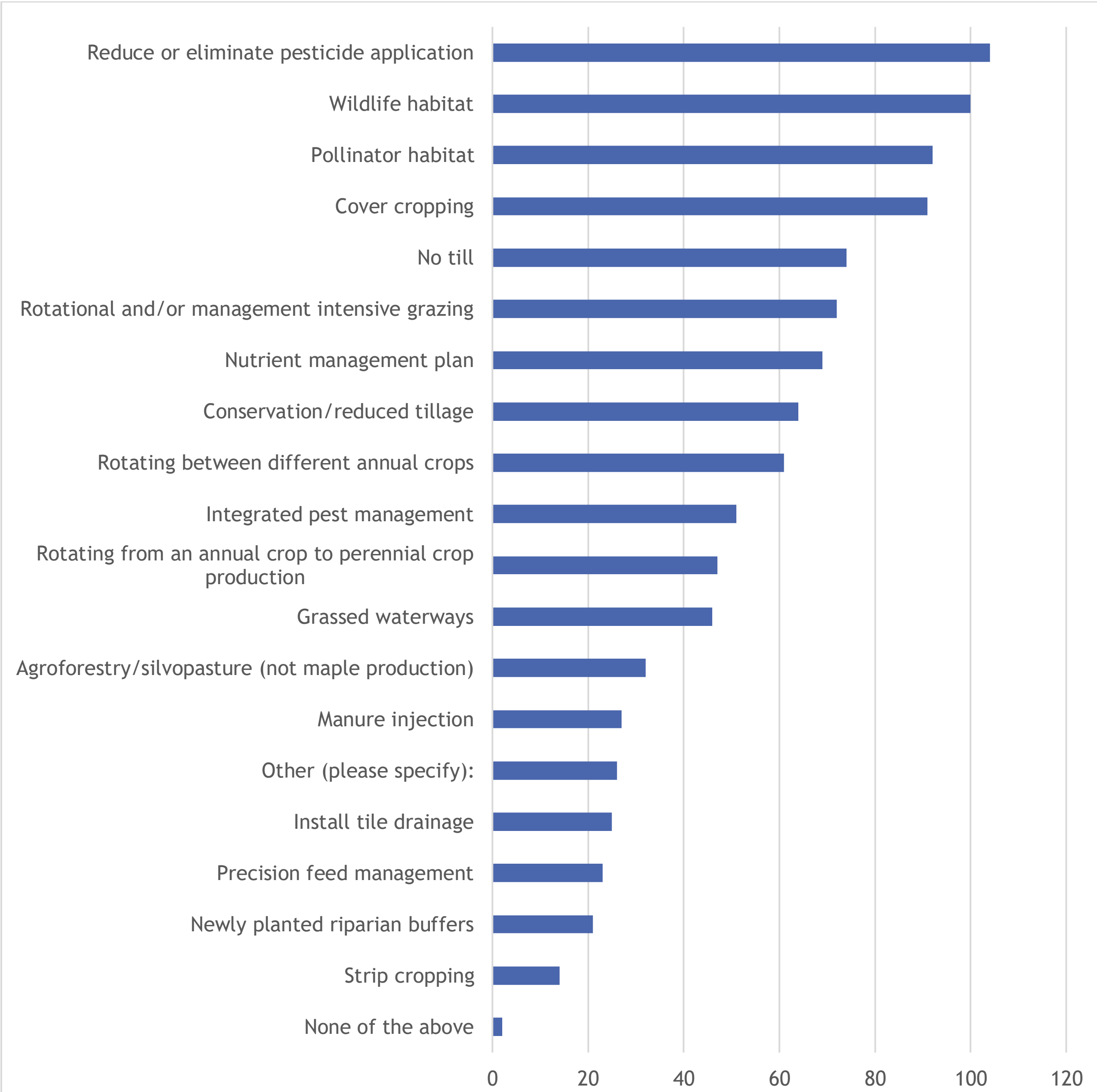


Figure 27. Conservation practices implemented by survey respondents.

Table 28. Conservation practices implemented by survey respondents.

Conservation practice	% of respondents who implement
Reduce or eliminate pesticide application	58%
Wildlife habitat	56%
Pollinator habitat	51%
Cover cropping	51%
No till	41%
Rotational and/or management intensive grazing	40%
Nutrient management plan	39%
Conservation/reduced tillage	36%
Rotating between different annual crops	34%
Integrated pest management	28%
Rotating from an annual crop to perennial crop production	26%
Grassed waterways	26%
Agroforestry/silvopasture (not maple production)	18%
Manure injection	15%
Other (please specify):	15%
Install tile drainage	14%
Precision feed management	13%
Newly planted riparian buffers	12%
Strip cropping	8%
None of the above	1%

In addition to the multiple choice options, respondents were also give the opportunity to identify other conservation practices. These additional responses included:

- Riparian and wetland buffers
- Bio-swales
- Using draft animals to reduce soil compaction and minimize erosion when working in fields
- Timed clipping behind grazing of invasive species
- Movement of mobile poultry housing
- Bale grazing to improve fertility
- Terraced to prevent erosion and flooding
- Soil augmentation through controlled burns and adding of charcoal
- Stockpile grazing
- Cut and drop syntropic practices

- Bedded pack
- Hugelkulture
- Swale permaculture
- Permanent perennial plantings
- Long term productive tree plantings and buffers
- On site compost production and applications
- Limits on # taps per tree in sugarbush
- Erosion elimination
- 50' forested buffer zone
- Regular mulching
- Spread cow manure on hay fields
- Beekeeping
- Diversion ditches
- Dedicated livestock lanes & farm roads
- Seasonal considerations for land use
- Buffers
- Organic certification
- Crop diversity in cover crops
- Reduced mowing
- Invasive removal
- Water ram-pump for irrigation
- Drip irrigation
- Organic fertilizers for slow release and minimizing runoff
- On farm plastic reduction
- Spader instead or rototiller for tillage
- Mixed annuals and perennials
- No spray
- Rotate between grazing and hay cutting
- Grass buffers
- Gras-legume mixes
- Research and innovation on farm
- Buffer maintenance

Extent of incentive program support for conservation implementation

Survey respondents were asked to identify how many acres they implement for each conservation practice, and how many acres of that implementation was supported by incentive programs.

Table 29. Extent of field scale conservation practice implementation among adopters, and percent of implementation supported by incentive programs.

Practice	**Percent of respondents who implement this practice**	**Among adopters, percent of field acreage with practice (mean) ***	**Percent of acres implemented without incentive support (mean)**	**Percent of implemented acres supported by incentive (mean)**
Cover cropping	51%	97%	71%	29%
Rotating from an annual crop to perennial crop production	26%	53%	86%	14%
Rotating between different annual crops	34%	87%	97%	3%
Strip cropping	8%	49%	89%	11%
No till	41%	72%	89%	11%
Conservation/reduced tillage	36%	72%	97%	3%
Manure injection	15%	42%	58%	42%
Rotational and/or management intensive grazing	40%	65%	82%	18%
*To calculate the percent of field acreage with the practice implemented, the cover cropping, rotations, strip cropping, no-till, and reduced tillage rows use the equation 'acres in practice /total acres in annual crops on the farm'. For the manure injection row, we use the equation: 'acres in practice /total acres in annual crops, hay and pasture on the farm'. For the rotational and/or management intensive grazing row, we use the equation: 'acres in practice /total acres in hay and pasture on the farm'.				

Table 30. Edge-of-field and whole farm conservation practice implementation among adopters, and percent of implementation supported by incentive programs.

Practice	**Percent of respondents who implement this practice**	**Percent of implementation* without incentive support (mean)**	**Percent of implementation* supported by incentive (mean)**
Nutrient management plan	39%	90%	10%
Integrated pest management	28%	93%	7%
Reduce or eliminate pesticide application	58%	96%	4%
Pollinator habitat	51%	95%	5%
Wildlife habitat	56%	91%	9%
Agroforestry/silvopasture (not maple production)	18%	93%	7%
Newly planted riparian buffers	12%	55%	45%
Grassed waterways	26%	92%	8%

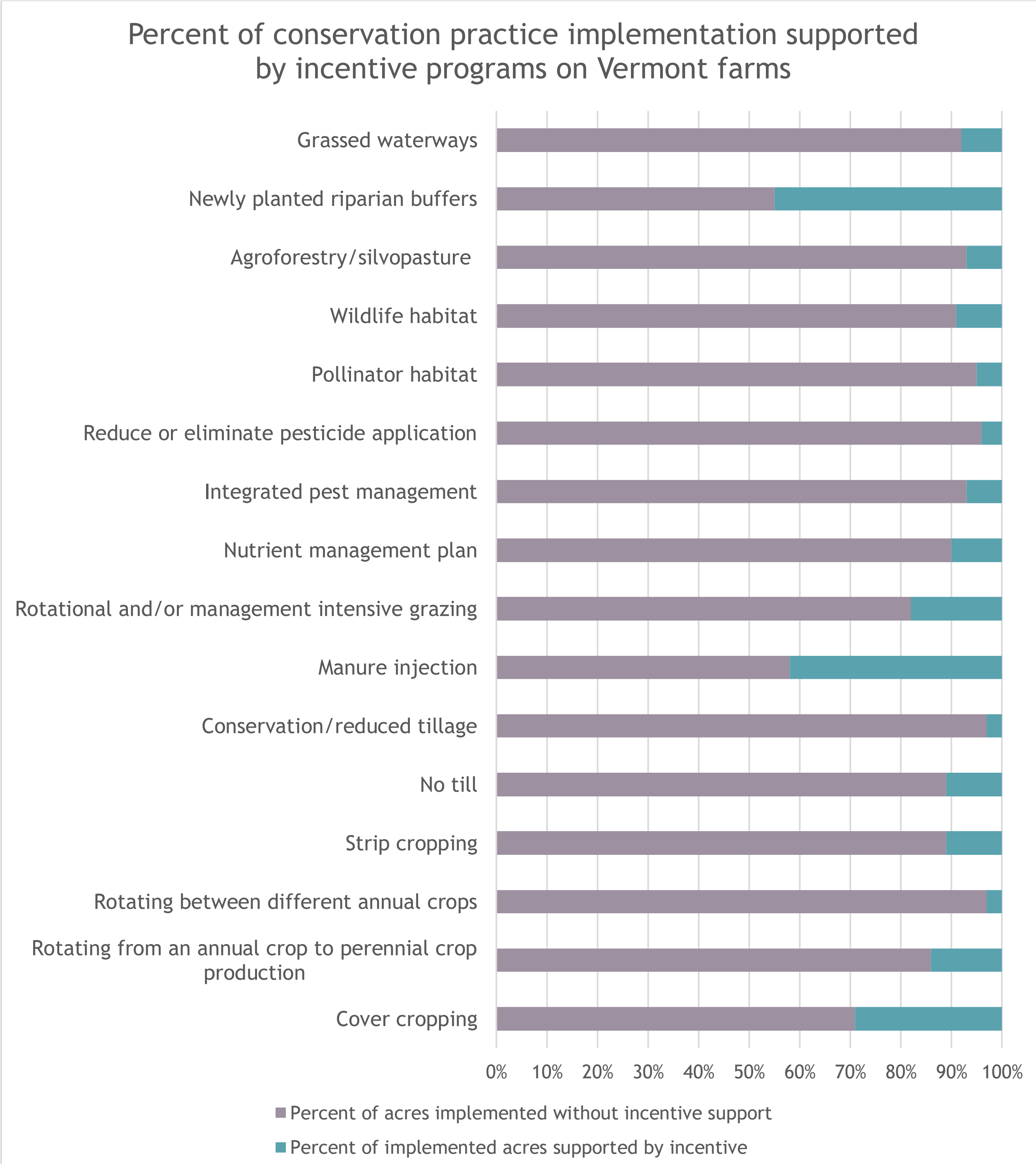


Figure 28. Funding for conservation practice implementation.

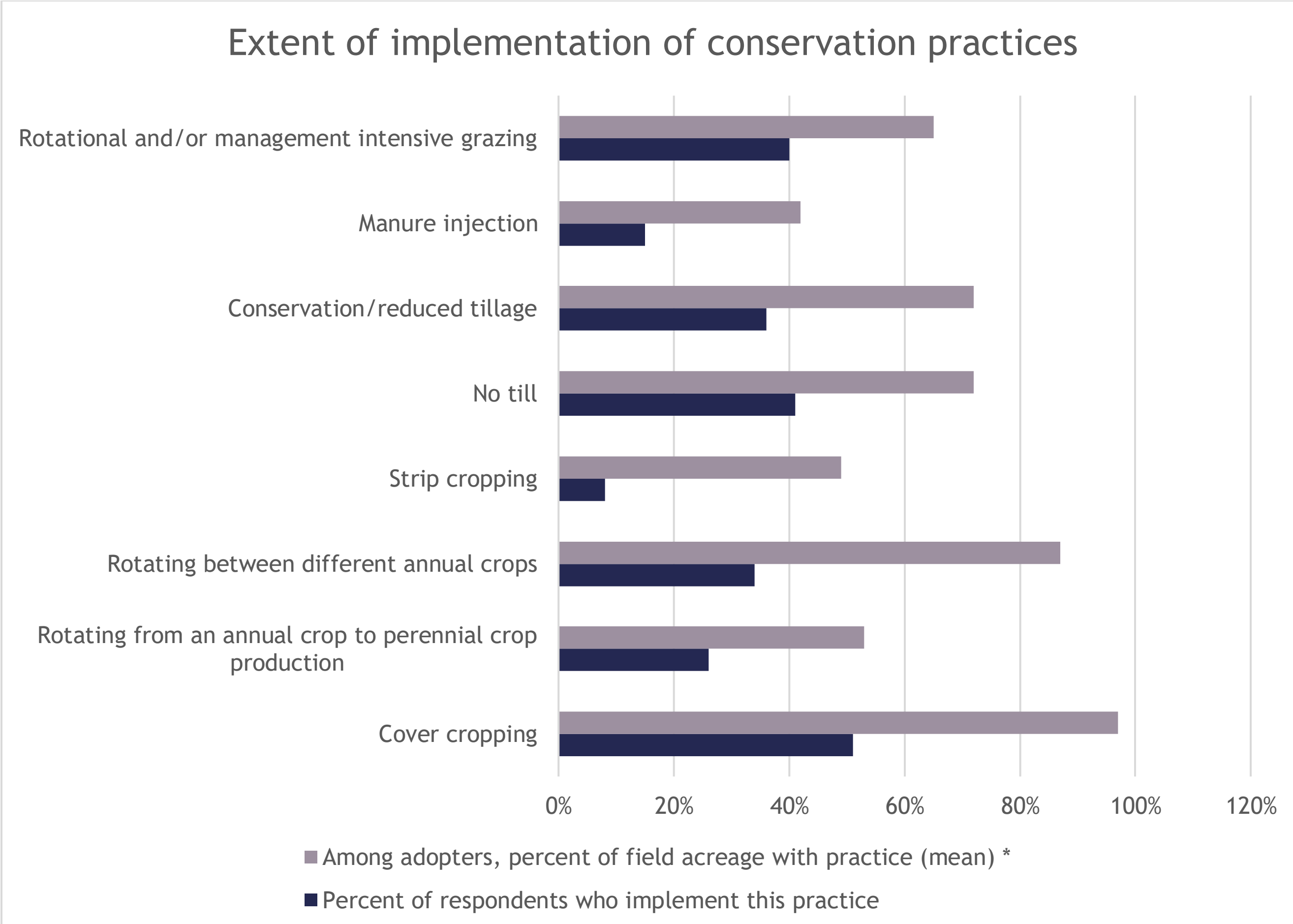


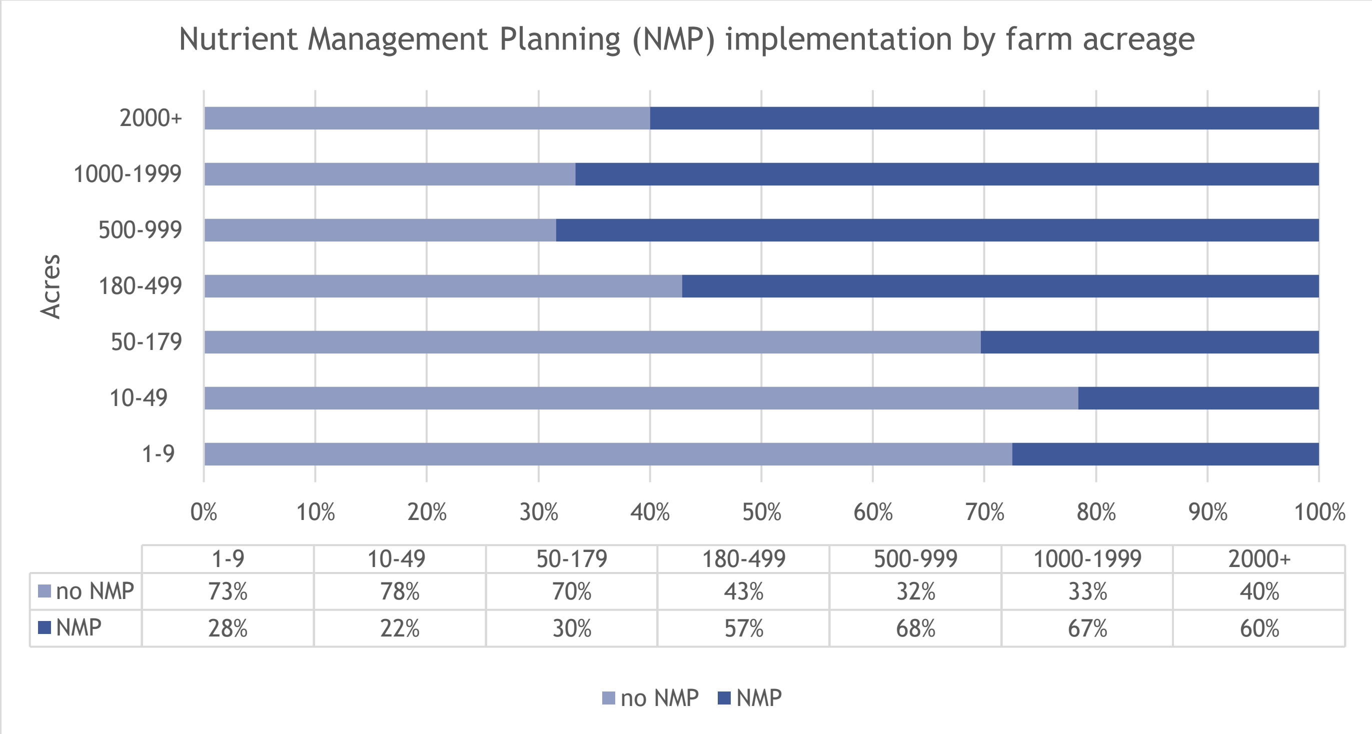
Figure 29. Percent of respondents who implement field scale practices, and the percent of their field acreage they implement these practice on. The figure provides a sense of the extent of adoption across farming community, and the extent of implementation on farms.

Precision feed management

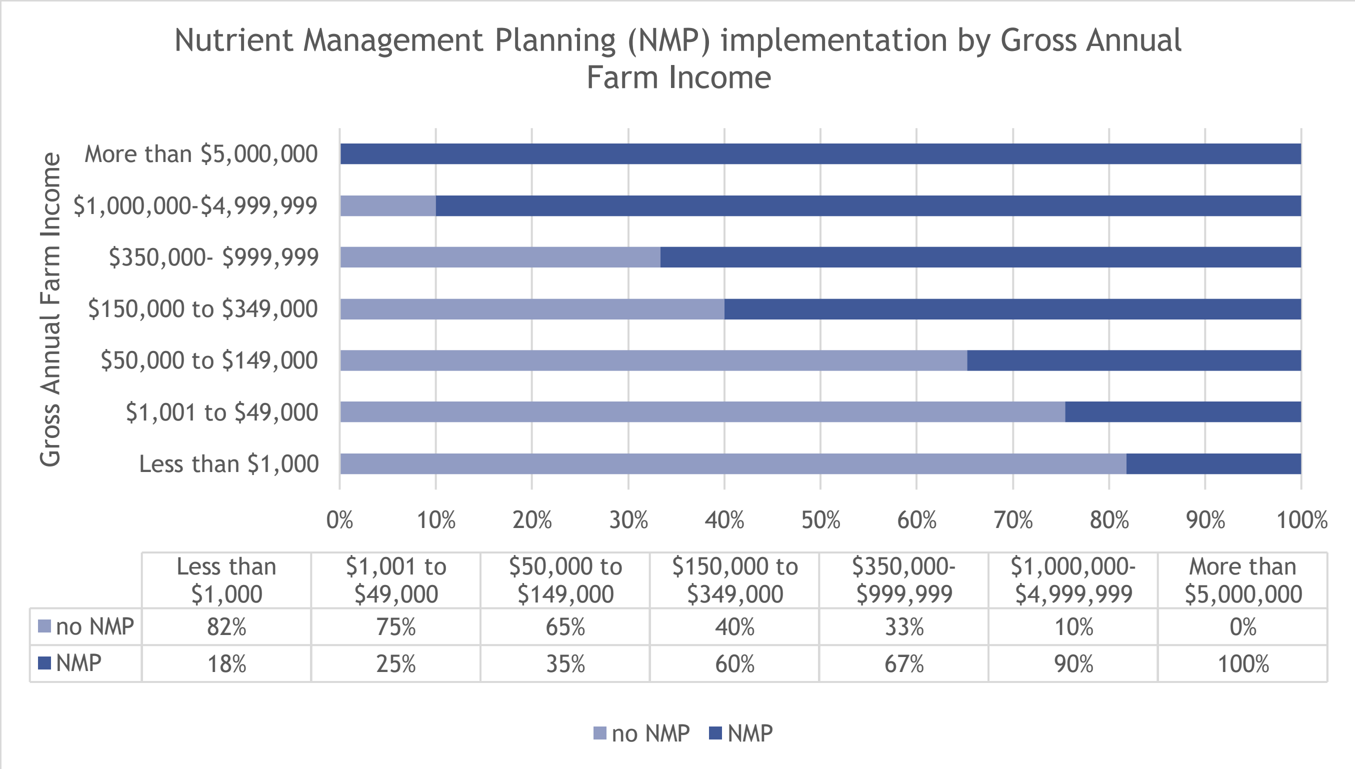
Table 31. Heard sizes and extent of precision feed management among survey respondents.

Statistic	Number
Range of herd sizes among survey respondents (min-max number of cows)	10-1600
Average number of cows on farm	429
Percent of respondents who implement this practice	13%
Among adopters, percent of heard fed with precision feed management	89%

Nutrient Management Planning by farm size



	1-9	10-49	50-179	180-499	500-999	1000-1999	2000+
no NMP	73%	78%	70%	43%	32%	33%	40%
NMP	28%	22%	30%	57%	68%	67%	60%



	Less than $1,000	$1,001 to $49,000	$50,000 to $149,000	$150,000 to $349,000	$350,000- $999,999	$1,000,000- $4,999,999	More than $5,000,000
no NMP	82%	75%	65%	40%	33%	10%	0%
NMP	18%	25%	35%	60%	67%	90%	100%

Q33. Please rank your top three reasons for implementing conservation practices.

Table 32. Primary motivations for implementing conservation practices, as ranked by farmers.

Motivation	Total mentions	Rank 1	Rank 2	Rank 3
Stewardship of your farmland	145	77	39	29
Stewardship of the environment off your farm (water quality, soil health, ecosystem health, wildlife/plant biodiversity)	121	41	52	28
Benefitting your community and landscape	74	3	17	54
Financial (farm viability, economics, long-term cost savings)	64	25	17	22
Compliance with agricultural laws (ex. VT RAPs)	33	5	18	10
Help with farm management issues (ex. Nutrient management)	30	3	15	12
Other	7	4	0	3

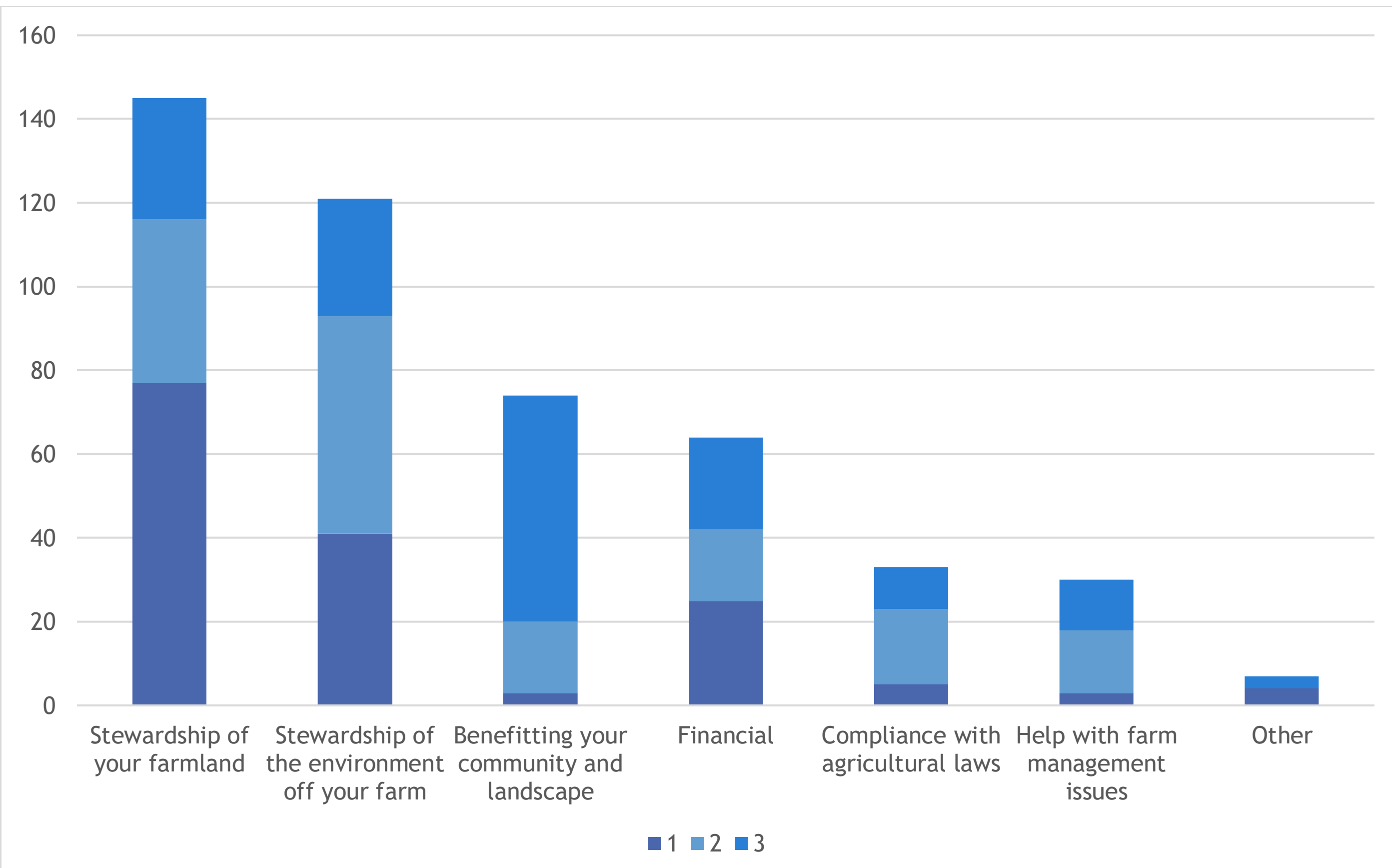


Figure 30. Primary motivations for implementing conservation practices, as ranked by farmers.

Q34. Please rank your top three reasons for enrolling in conservation programs.

Table 33. Primary motivations for enrolling in conservation practices, as ranked by farmers.

Motivation	Total mentions	Rank		
		1	2	3
Stewardship of your farmland	113	38	60	15
Stewardship of the environment off your farm	100	26	36	38
Financial	98	67	12	19
Help with farm management issues	40	9	15	16
Benefitting your community and landscape	37	4	8	25
Compliance with agricultural laws	31	1	7	23
Other	17	13	3	1

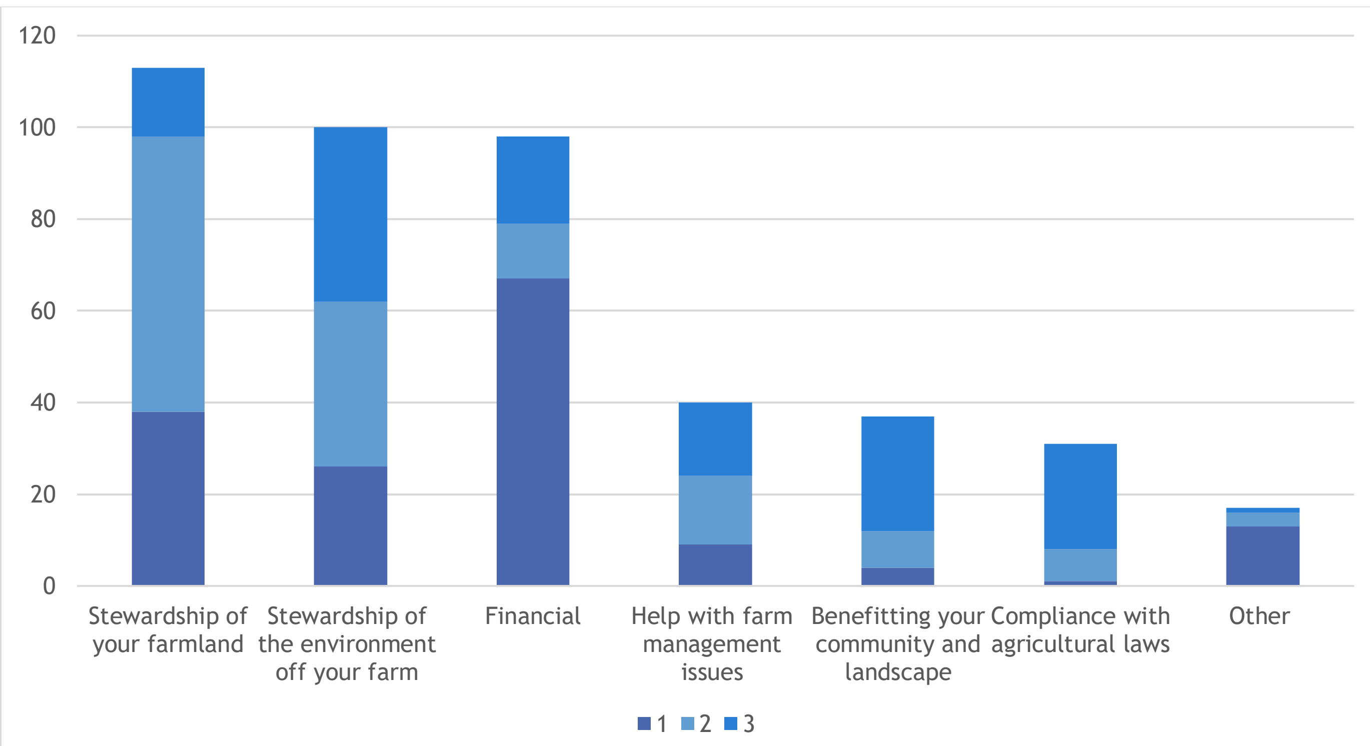


Figure 31. Primary motivations for enrolling in conservation practices, as ranked by farmers.

Q35. What state or federal conservation programs have you enrolled in? (including currently enrolled) (check all that apply)

Table 34. Programs respondents have enrolled in.

Answer	# of respondents enrolled
I am not enrolled in any state or federal conservation programs	56
NRCS Environmental Quality Incentive Program (EQIP)	70
FSA Conservation Reserve Enhancement Program (CREP)	17
NRCS Conservation Stewardship Program (CSP)	27
VAAFM Vermont Pay for Phosphorus (VPFP)	9
VAAFM Farm Agronomic Practice (FAP)	31
VAAFM Best Management Practices (BMP)	25
VAAFM Pasture and Surface Water Fencing (PSWF)	8
Other	11

Other programs identified by respondents:

- NRCS forestry CAP
- Federal Grasslands conservation Program
- Use Value
- VESP
- Ben & Jerry's Caring Dairy
- NRCS/WRE program

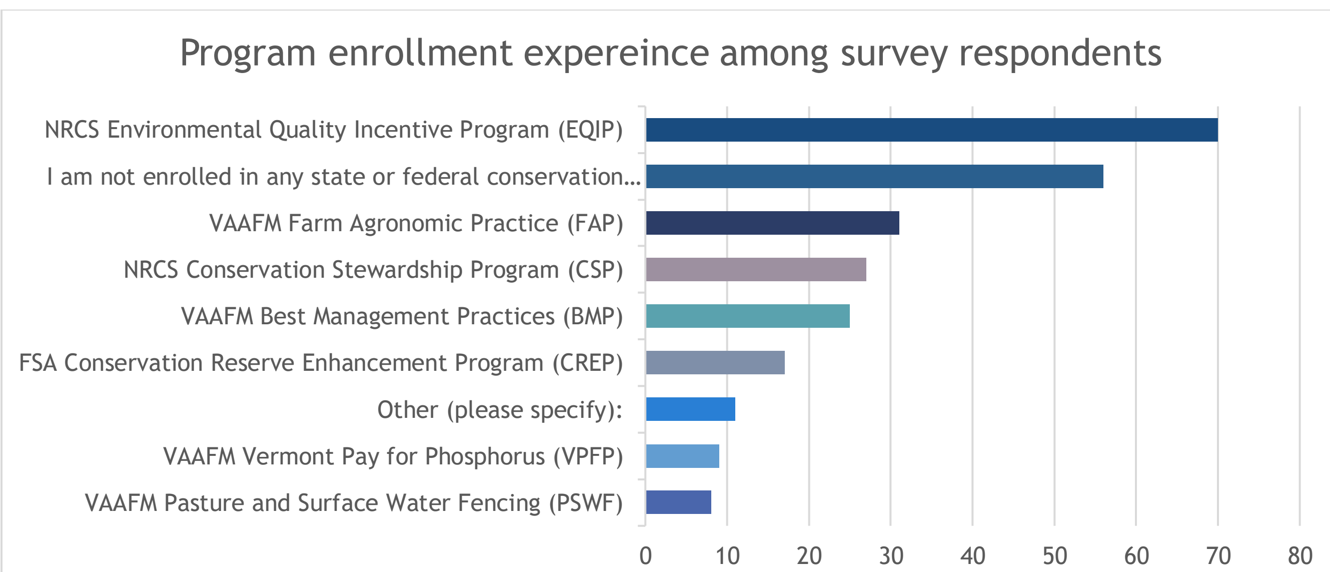


Figure 32. Programs respondents have enrolled in.

Q36. Do you grow corn, soybeans, or other row crops that are subsidized by the government?

Table 35. Percent of respondents who grow subsidized crops.

Answer	%	Count
Yes	16.22%	30
No	83.78%	155

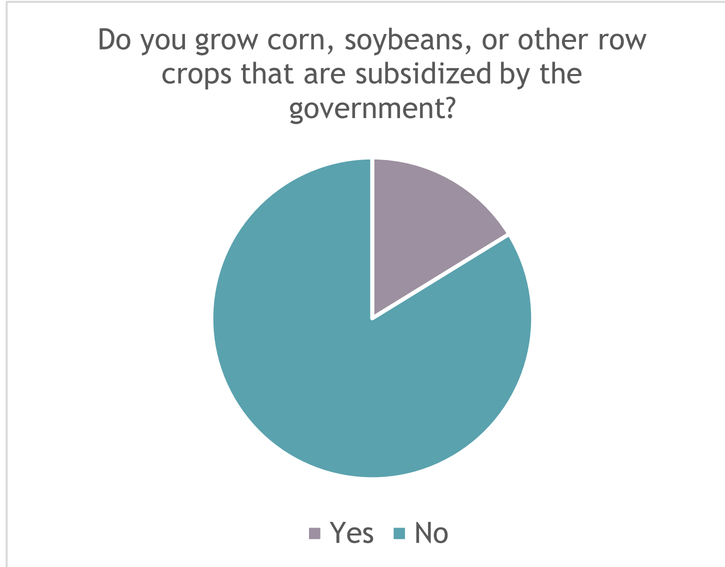


Table 36. Type of subsidy programs enrolled in, for the farms who participate in subsidy programs.

Answer	%	Count
USDA Market Facilitation Program (MFP)	20.69%	6
USDA Agricultural Risk Coverage- Price Loss Program (ARC-PLP)	75.86%	22
Other	3.45%	1

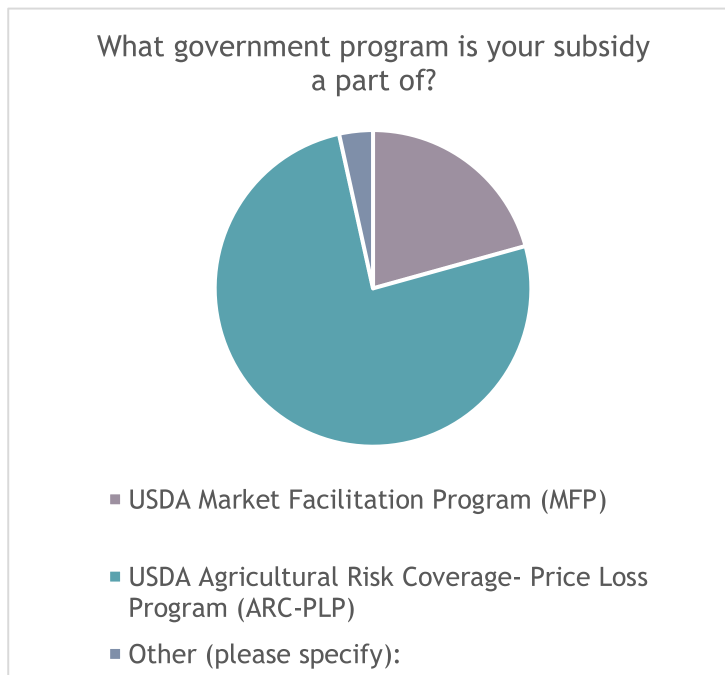


Table 37. Percent of annual farm income that is from subsidy, for farms that participate in those programs.

Answer	%	Count
0-25%	79.31%	23
25-50%	13.79%	4
50-75%	6.90%	2
75-100%	0.00%	0

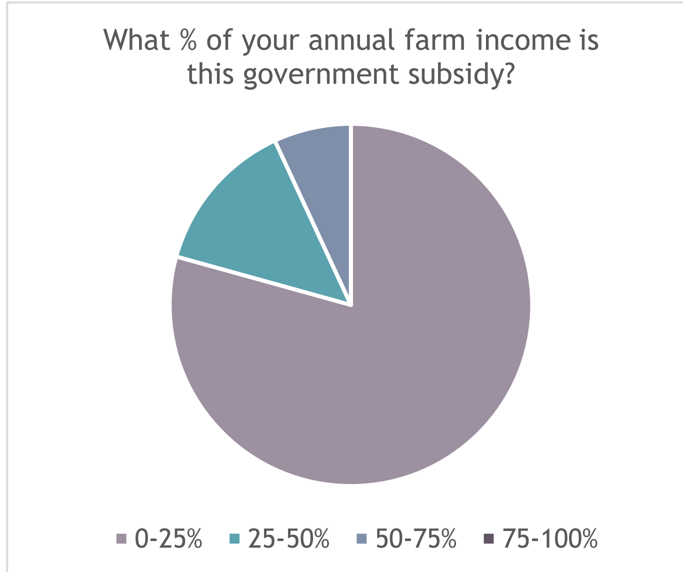
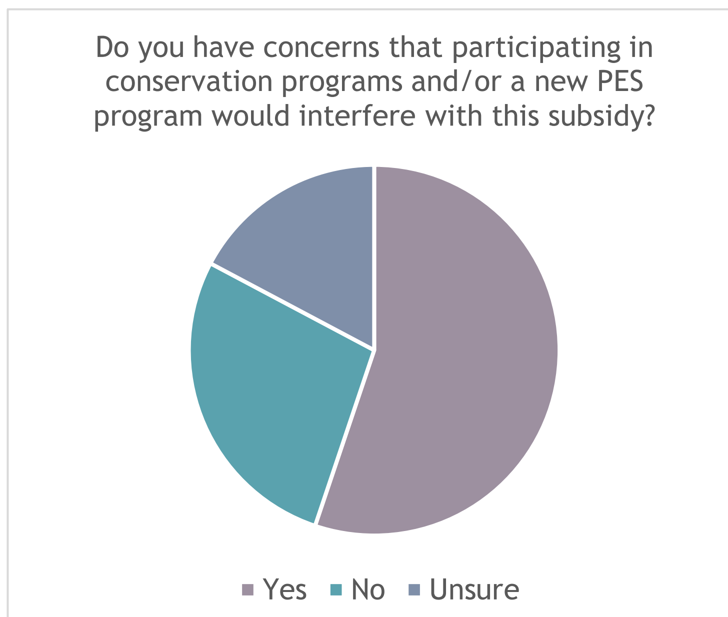


Table 38. Percent of farmers who are concerned about interactions between a new PES program and subsidy.

Answer	%	Count
Yes	55.17%	16
No	27.59%	8
Unsure	17.24%	5

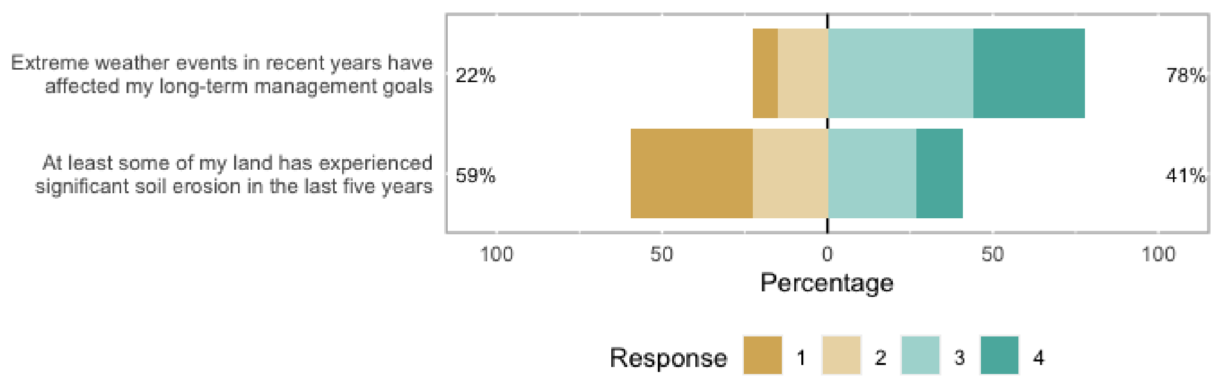


Section 5. Motivations, capability & beliefs

Survey respondents were asked to provide their opinions and level of agreement with a series of statements about perceived responsibility, capacity, vulnerability, and beliefs on a level of 1 to 4, where 1 was disagree and 4 was agree.

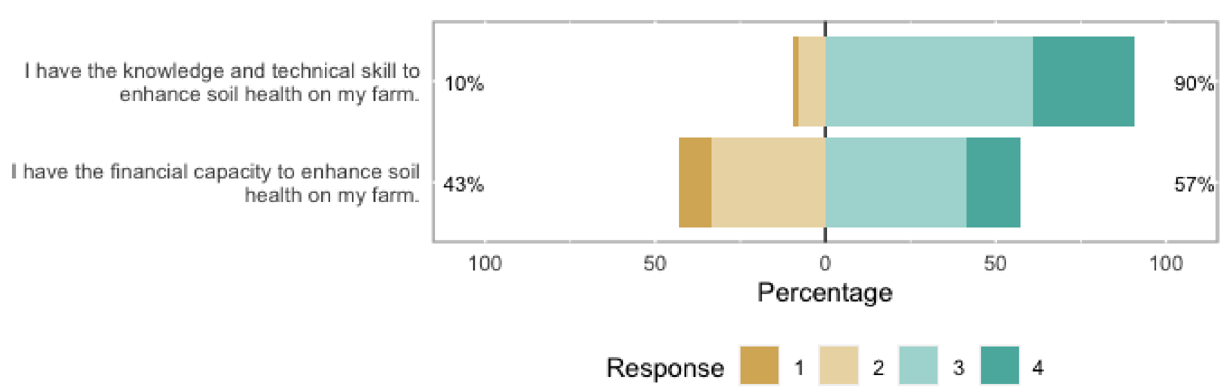
Perceived vulnerability

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
Extreme weather events in recent years have affected my long-term management goals	7.19%	20.92%	41.18%	30.72%
At least some of my land has experienced significant soil erosion in the last five years	34.64%	21.57%	32.03%	11.76%



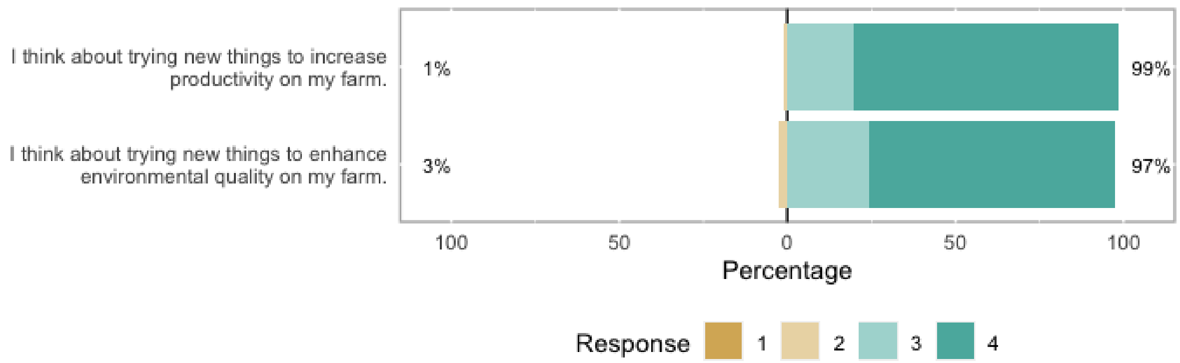
Perceived capability

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
I have the knowledge and technical skill to enhance soil health on my farm.	1.31%	7.19%	64.71%	26.80%
I have the financial capacity to enhance soil health on my farm.	9.15%	32.03%	45.10%	13.73%



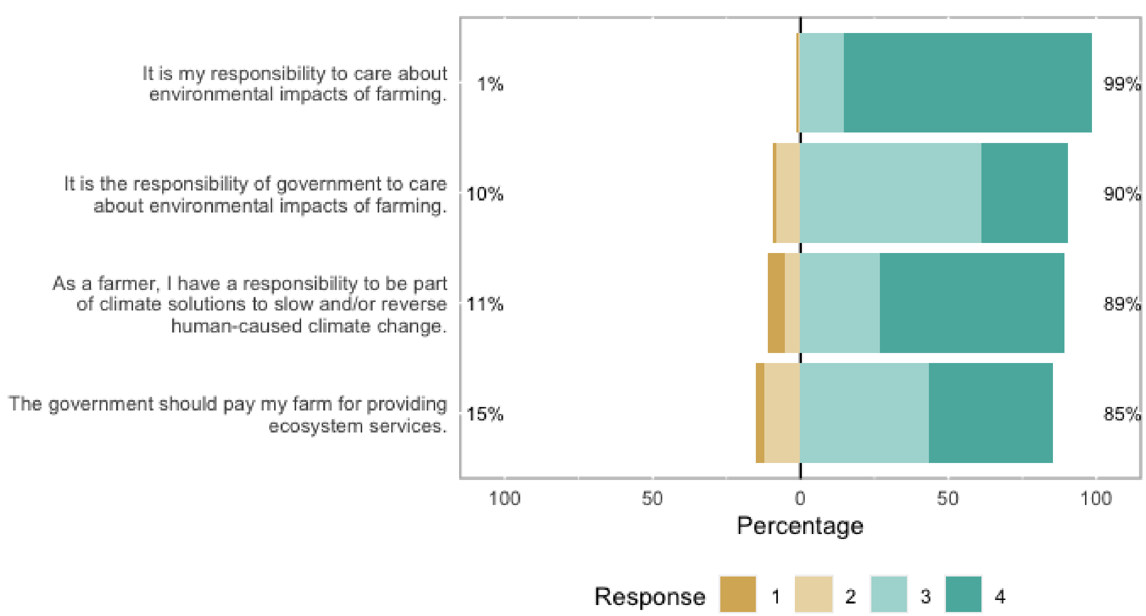
Innovative intent

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
I think about trying new things to enhance environmental quality on my farm.	0.00%	2.61%	23.53%	73.86%
I think about trying new things to increase productivity on my farm.	0.00%	0.65%	24.84%	74.51%



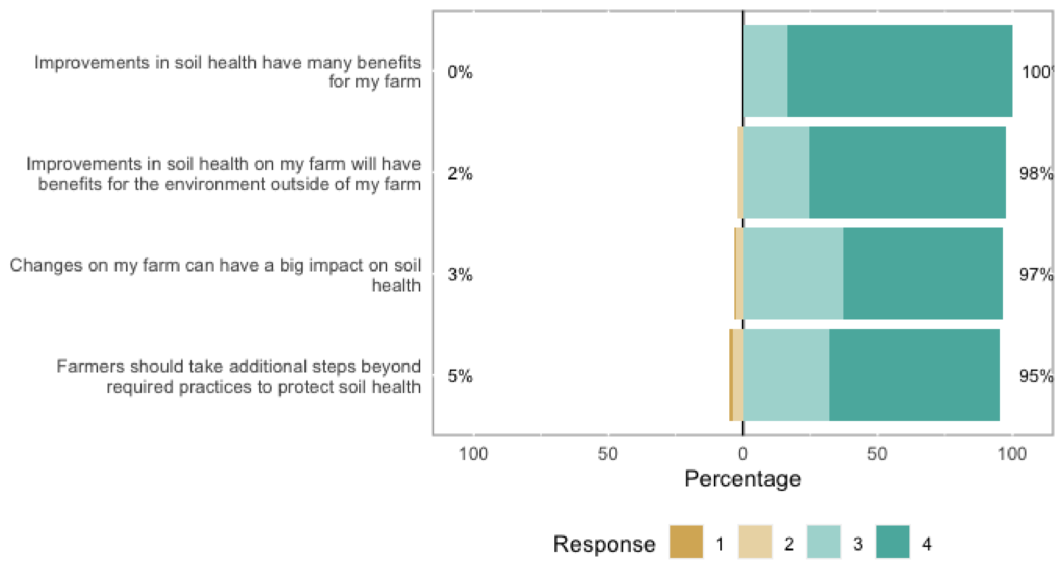
Responsibility

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
It is my responsibility to care about environmental impacts of farming.	0.00%	7.19%	13.07%	79.74%
It is the responsibility of government to care about environmental impacts of farming.	5.88%	9.15%	32.68%	52.29%
As a farmer, I have a responsibility to be part of climate solutions to slow and/or reverse human-caused climate change	4.58%	5.23%	32.03%	58.17%
The government should pay my farm for providing ecosystem services.	2.61%	11.11%	40.52%	45.75%



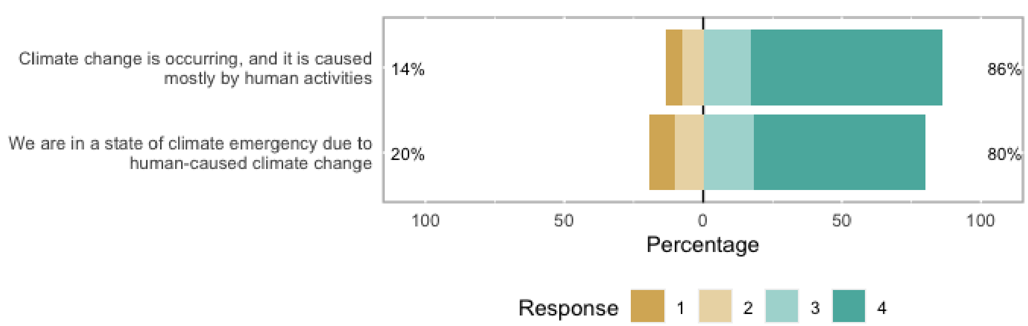
Soil health & farming

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
Improvements in soil health have many benefits for my farm	0.00%	0.00%	15.03%	84.97%
Improvements in soil health on my farm will have benefits for the environment outside of my farm	0.00%	1.31%	29.41%	69.28%
Changes on my farm can have a big impact on soil health	0.65%	2.61%	41.18%	55.56%
Farmers should take additional steps beyond required practices to protect soil health	0.65%	3.92%	35.95%	59.48%



Climate change belief

Statement	Disagree	Somewhat disagree	Somewhat agree	Agree
Climate change is occurring, and it is caused mostly by human activities	5.88%	6.54%	15.69%	71.90%
We are in a state of climate emergency due to human-caused climate change	8.50%	9.80%	23.53%	58.17%



Section 6. Information Sources

Survey respondents were asked to identify the top three sources of information they use when making farm management decisions.

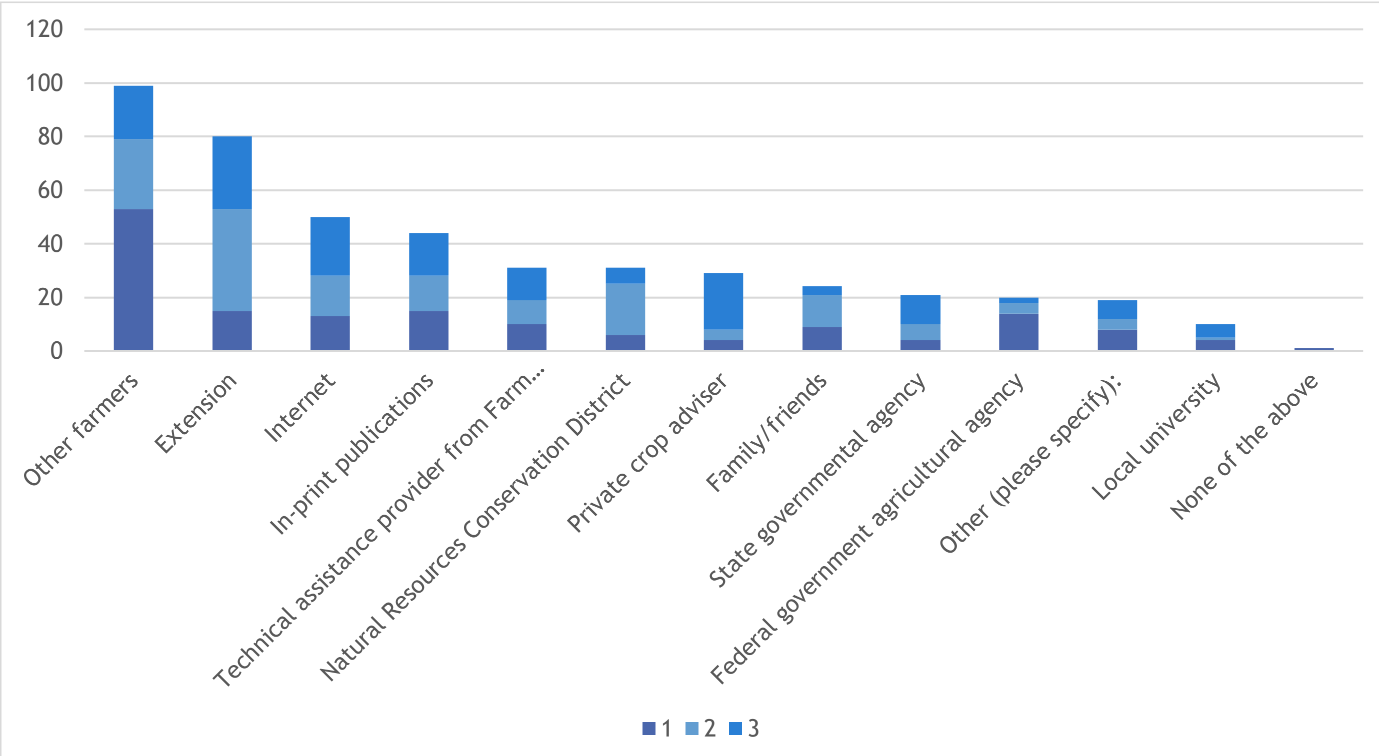


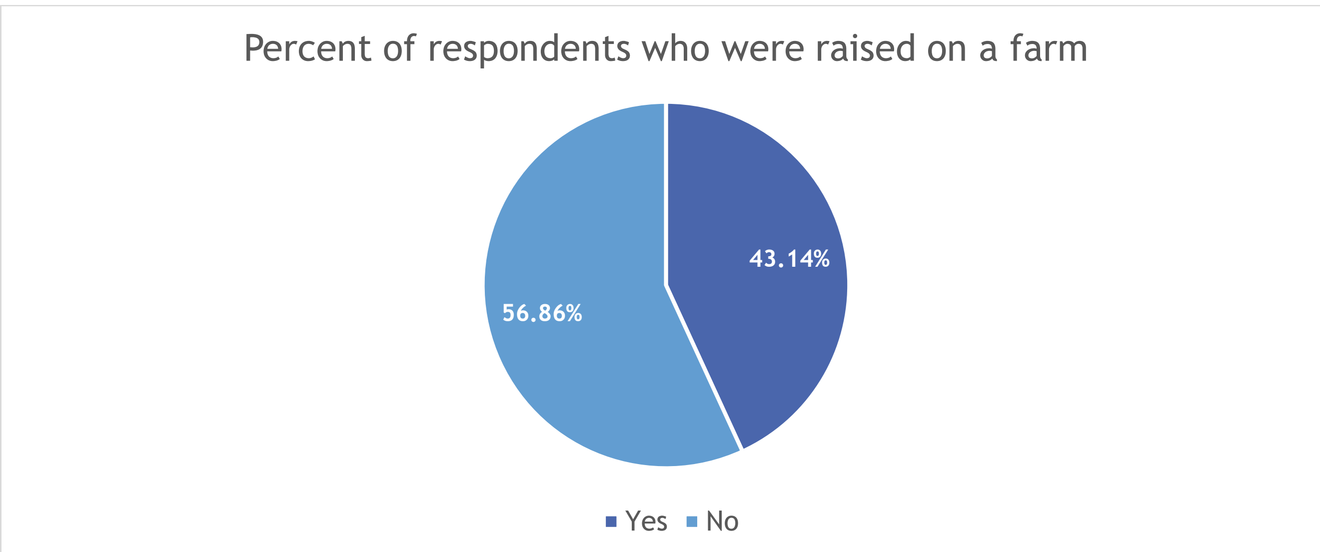
Table 39. Preferred sources of information by Vermont farmers.

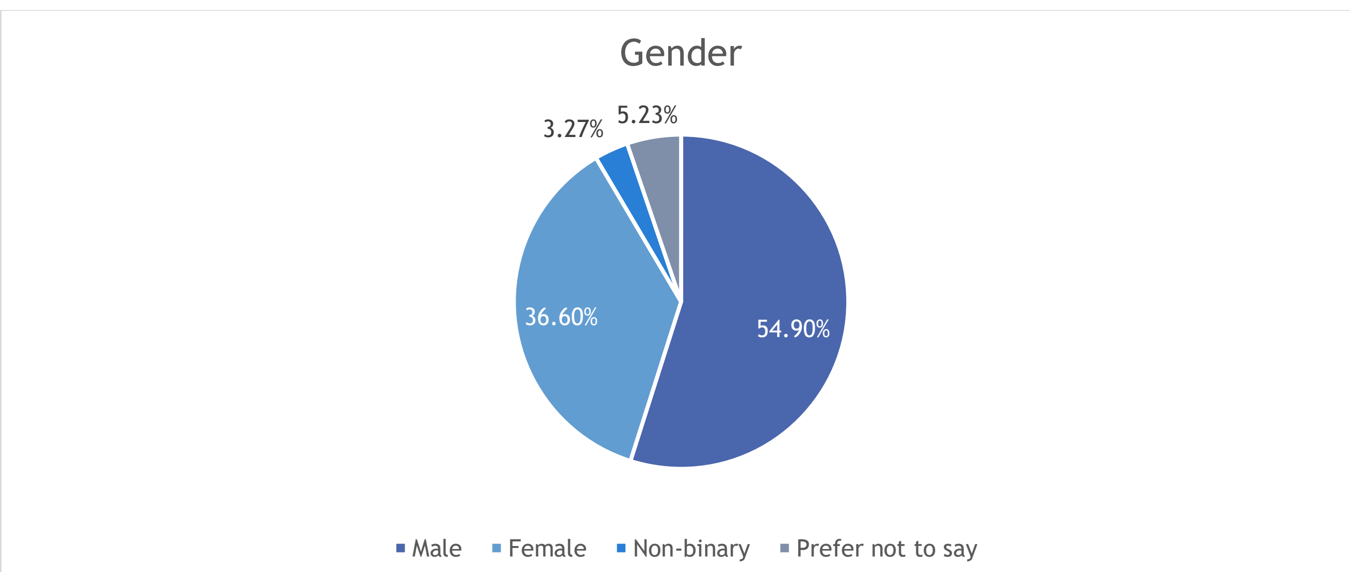
Preferred information source	Total mentions	Rank #1	Rank #2	Rank #3
Other farmers	99	53	26	20
Extension	80	15	38	27
Internet	50	13	15	22
In-print publications	44	15	13	16
Technical assistance provider from Farm Viability Network (NOFA, Intervale, etc.)	31	10	9	12
Natural Resources Conservation District	31	6	19	6
Private crop adviser	29	4	4	21
Family/friends	24	9	12	3
State governmental agency	21	4	6	11
Federal government agricultural agency	20	14	4	2
Other	19	8	4	7
Local university	10	4	1	5
None of the above	1	1	0	0

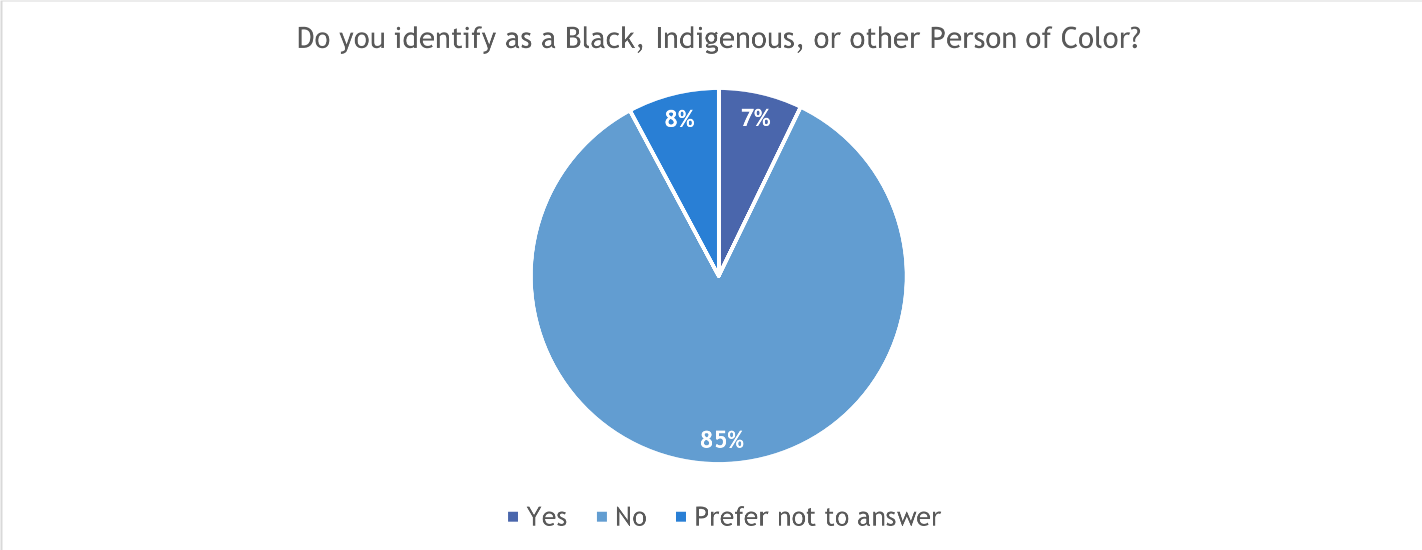
Section 7. Respondent characteristics & demographics

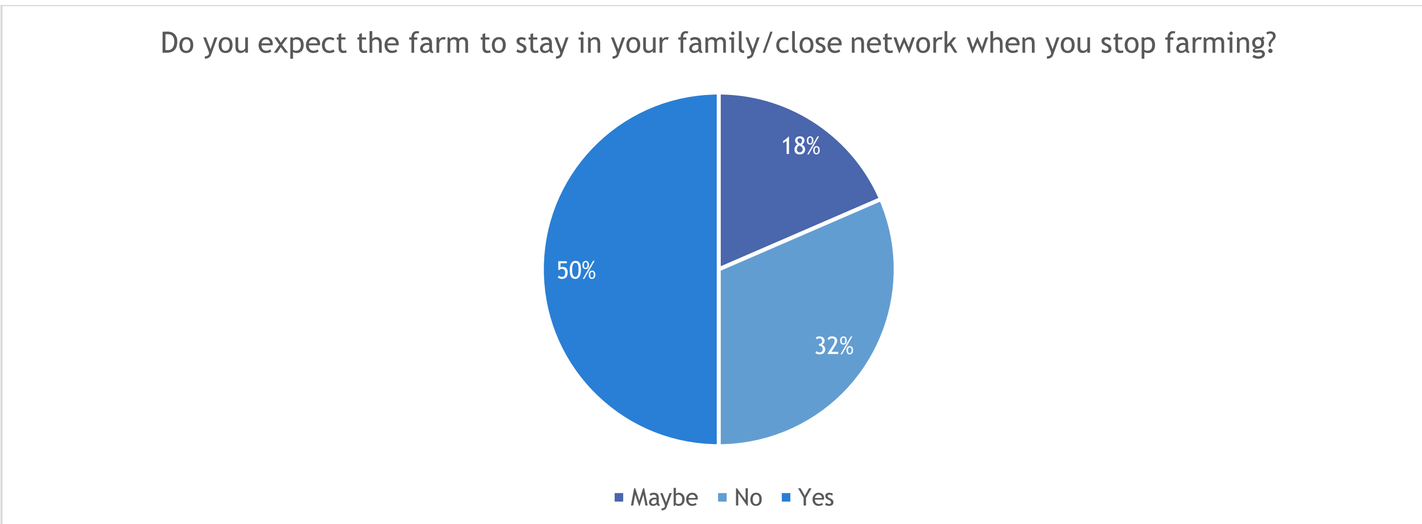
Table 40. Descriptive statistics of respondents' age, experience and intended years of farming in the future.

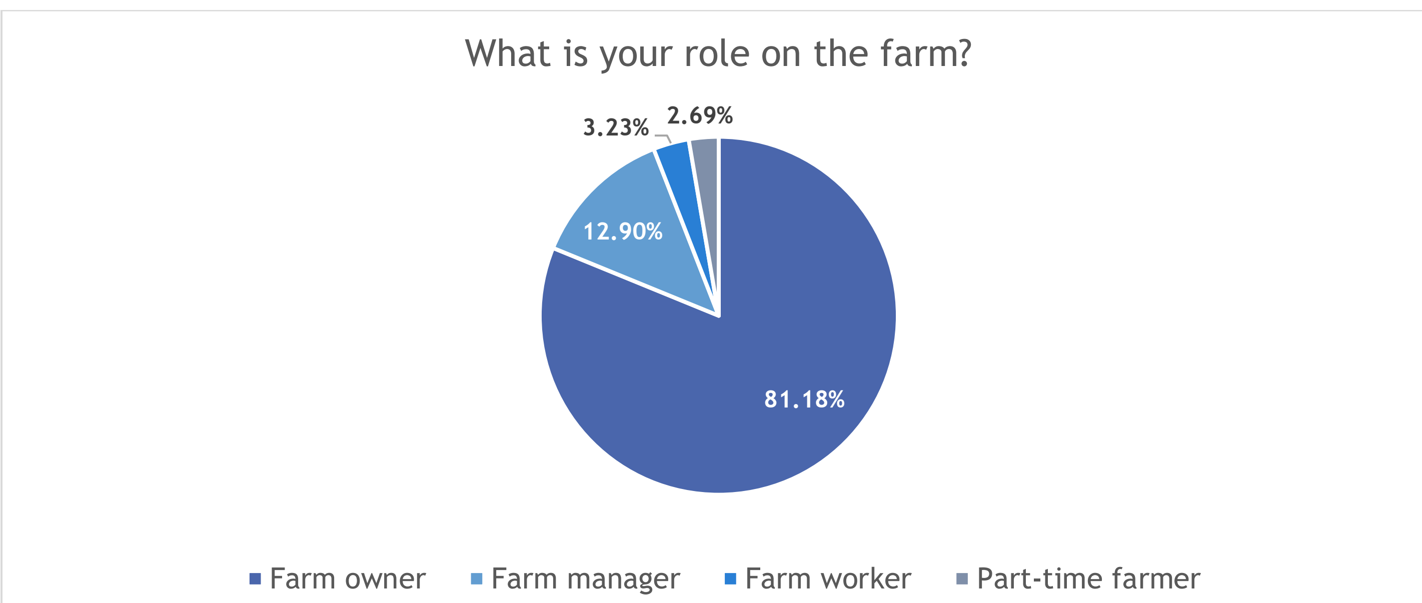
	Age	Years of farming experience	Intended years of future farming
Min	24	1.5	0
Mean	49	21	24
Median	46	15	20
Max	77	63	55

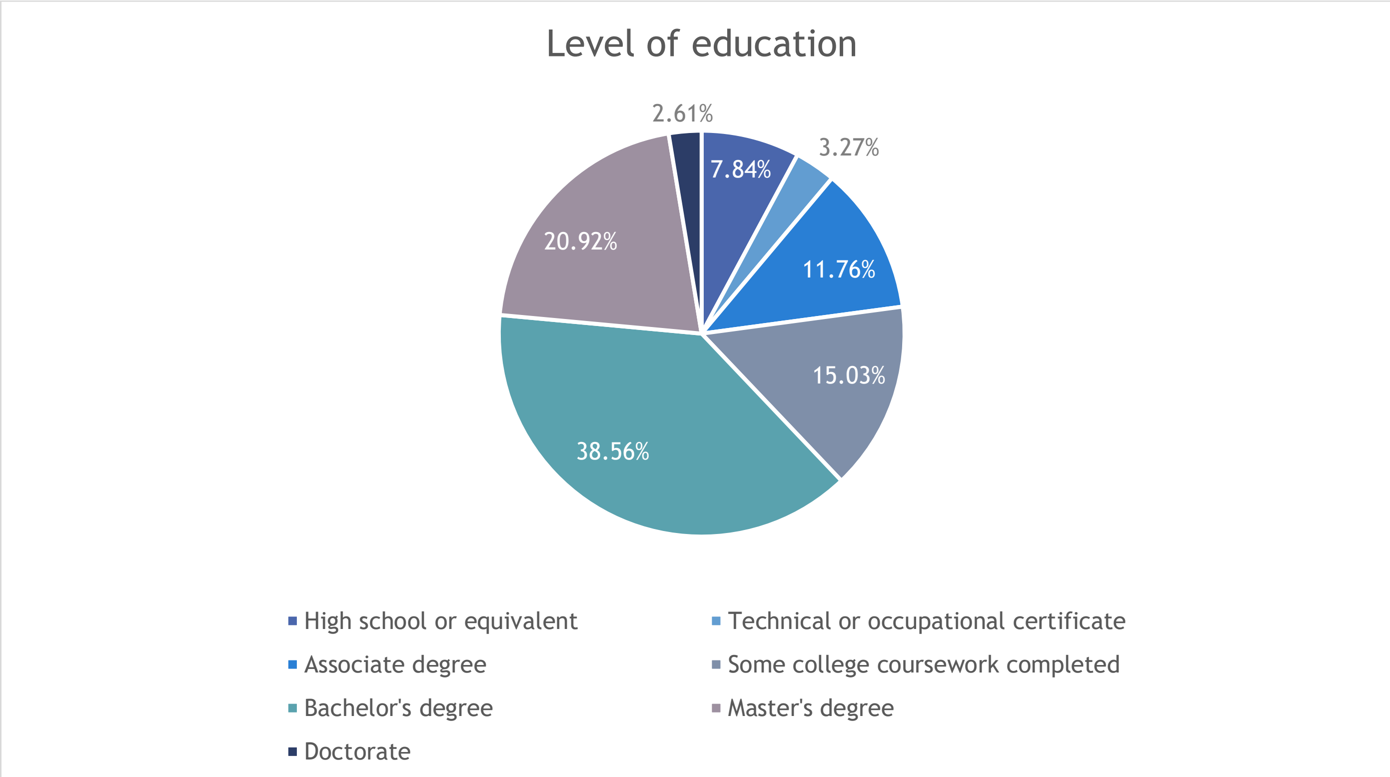





Do you identify as a Black, Indigenous, or other Person of Color?
8%
7%
85%
Yes
No
Prefer not to answer


Do you expect the farm to stay in your family/close network when you stop farming?
18%
50%
32%
Maybe
No
Yes


What is your role on the farm?
3.23%
2.69%
12.90%
81.18%
Farm owner
Farm manager
Farm worker
Part-time farmer



Answer	% of respondents
High school or equivalent	7.84%
Technical or occupational certificate	3.27%
Associate degree	11.76%
Some college coursework completed	15.03%
Bachelor's degree	38.56%
Master's degree	20.92%
Doctorate	2.61%

The University of Vermont

Farmer Perspectives on Administrative Burdens & Potential Compensation Structures:

A Short Summary Report of Farmer Interviews from Spring 2022

Vermont Payment for Ecosystem Services Technical Research Report #3c

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

August 2022

Contributors: Ellen Friedrich, Nour El-Naboulsi, Alissa White, and Heather Darby

Gund Institute for Environment

The University of Vermont Extension

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Acknowledgements:

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Key Messages

Interviews with 35 Vermont farmers explored their perspectives on compensation associated with a soil health payment for ecosystem services (PES) program. Farmers' willingness to participate in a soil health PES is linked to both the burden of enrollment paperwork and the payment level, among other factors.

If deciding whether to participate in a soil health PES program, nearly all farmers said they would weigh the time and energy put into the administrative workload against the perceived benefits and value of the program, i.e., the payment level or technical assistance provided. Farmers appreciate straightforward program applications and paperwork that are aligned with their interests and schedules. Understandable language and access to technical assistance is also important to farmers when applying to programs and/or handling paperwork. A PES program should be as straightforward as possible to ease administrative burdens. At a minimum, compensation should reflect the paperwork and engagement burden for farmers.

100% of the farmers we interviewed highly valued soil health on their farms. Most farmers liked the idea of a PES program which compensates them for soils with good health. They appreciated how a program could enable and/or incentive them to maintain or improve soil health on their farms. Farmers identified the importance for a soil health program to consider differences between farms and soils when setting reasonable performance expectations and payment rates.

Farmers expressed a wide variety of different perspectives and preferences about what payment rates would be meaningful to them in a PES program. There did not seem to be a 'one-size-fits-all' level of payment, and associating payment levels with soil health metrics proved challenging for some farmers. While many farmers were able to provide estimates of the level of payment they would be willing to accept, some were either unwilling or unable to determine appropriate levels of payment based on soil health metrics. Most farmers thought about the investment of time and resources needed when thinking about payment rates. Overall, the average level of payment that would be meaningful at the whole farm level described by interviewees was $9,322.00 per farm. However, significant differences in payment levels were detected by farm acreage. Farmers with fewer acres tended to require higher per acre payment rates than farmers with more acres. Conversely, farmers with larger acreage tended to require higher total payment. Approximately 90% of farmers interviewed were supportive of per acre payments in a soil health PES program. Nearly 50% of interviewees expressed concerns about how undifferentiated per acre payment rates across different farm types would favor the participation of farms with more acres and those which were less intensively managed.

The potential value of a soil health PES program was widely recognized to be more than just monetary. Farmers expressed interest in both the monetary and non-monetary benefits that a potential program might offer them. Most were interested in the program providing some combination of financial payments, access to farm-specific data, connection to a farmer network/learning community, and technical assistance.

Introduction & Methods

To support the Vermont Soil Health and Payment for Ecosystem Services Working Group in determining appropriate payment rates for farmers, our team conducted 35 in-depth interviews with Vermont farmers in March and April of 2022. The interviews were designed to complement a survey that was administered in early 2022 to 179 farmers (the 2022 Vermont Farmer Conservation & Payment for Ecosystem Services Survey). After completing the survey, respondents were invited to participate in a follow-up interview. Compensation was offered to ensure participation in the interviews from a greater diversity of farmers.

The interviews were intended to solicit farmers' perspectives on compensation for a PES program that may base payments on measured soil health metrics. A semi-structured interview format with questions about administrative burden, compensation structures, and acceptable and meaningful payment rates was approved by UVM IRB (#STUDY00001466). Interviews were conducted over the phone or video-conference call. Conversations lasted approximately 50 minutes and were recorded and then transcribed verbatim. We used an open coding approach to identify themes emerging across the transcripts using NVivo software. Interviews were thematically coded by two researchers who met and compared their coding after reading the first few transcripts. Inter-coder reliability was evaluated within NVivo and found to be at acceptable levels (kappa of 0.45). All of the transcripts were then double-coded, and the thematic analysis was summarized. This report highlights key messages from the results of this process.

Table 1. Participant age expected years of farming, and years of farming experience.

	Minimum	Average	Maximum
Age of Farmer	24	49	76
Years of Farming Experience	3	24	50
Expected Years of Farming Left	3	27	50

Farmer & Farm Characteristics

Of the 35 farmers interviewed, 63% were male, 31% were female and 5% declined to identify a gender. The average age of participants was 49. Eight of the interviewees are dairy farmers, ten sell hay, 15 have animals, and approximately half are smaller and more diversified operations. 17 of the interviewees manage farms with less than 50 acres, 18 manage more than 50 acres. Basic descriptive statistics of participants' education, income, farming experience, and intended future farming are displayed in Tables 1 & 2.

Table 2. Participant education and farm income.

	Number of Respondents	Percent of Respondents
Highest Level of Education		
Less than a Bachelor's degree	9	26%
Bachelor's degree	17	49%
More than a Bachelor's degree	11	31%
Gross Annual Farm Income		
Less than $1,000	1	3%
$1,001 to $49,000	15	43%
$50,000 to $149,000	4	11%
$150,000 to $349,000	5	14%
$350,000- $999,999	9	26%
$1,000,000 or more	1	3%

Administrative Burden

Interviews started with a discussion about farmers' experience with conservation incentive programs. Farmers were asked about how administrative work influenced their participation in programs, and if they had ever decided not to enroll in a program because of paperwork. Farmers were then asked about how these concerns about paperwork and administrative burden would influence their decisions to enroll in a new PES program. Nearly all farmers said that they weigh the administrative burden— the time and energy put into the administrative workload—against the benefits offered by the program, when deciding whether to participate in a conservation incentive program. Farmer perspectives on the acceptable amount of program administrative paperwork were linked to the perceived program benefit, their own workloads/schedules, and the time they had to spend on administrative paperwork. While none of the farmers seemed to relish paperwork, there was a range to how much they were bothered or deterred by it. Approximately 30% of farmers interviewed cited administrative burdens as a major deterrent to participation in conservation incentive programs.

> *I guess the administrative burden [needs to be] in proportion to the perceived benefit. So things that are asking for farmer feedback or farmer participation that don't have a benefit—not necessarily directly to me but to the farm and to the land base— are far less appealing. I think that in this situation… because the program is trying to do something or helps me do something that is already in alignment with the goals of the farm that the administrative burden would be easier to stomach.*

> *[First] I try to determine if I'm going to even apply or look at it. I look at: What's the potential I'll be awarded [from] the contract? How much is the contract? How much time I'll have to invest in the contract? Is it worthwhile financially to invest?*

> *It [how burdensome paperwork is] kind of depends on the time in the year. If… I'm not busy doing a lot of field work or something like that, then I guess my time in the office maybe isn't worth quite so much as it is in the middle of the growing season.*

> *My time's not free. Every hour I spend in the office working on that, I could either be doing book work for the farm or doing actual physical work on the farm.*

Language and Technical Assistance: The language used by the program, and administrative technical assistance provided, helps determine how easy and inviting a program is for farmers to engage with, understand, and, ultimately, participate. Farmers appreciate the use of clear, understandable language and readily available assistance from experienced/knowledgeable program staff.

> *Applications can be intimidating and confusing because they're often written in languages that... The wording is such that it's... you wonder who wrote if. If there's somebody that's familiar with it on the other end, such as yourself or whatever, that's what makes it easier.*

When I see a USDA grant that's got tons of paperwork and very little help, I definitely am not going to apply for that because it's very complicated. I don't have time to have really complicated applications that I don't know that I'm going to get. I don't mind putting time in if I know that I'm going to receive a service, like my NCRS greenhouse, it's very simple. My NRCS representative, he made it very easy for me. So it was very easy to go through the process with him.

Compensation for Administrative Work: Farmers' opinions on whether monetary compensation was needed for administrative work varied. Many thought that compensation for administrative burdens was not necessarily needed, as long as the program participation benefits were enough, and the process wasn't overly onerous or unaligned with their own goals and schedules. However, some farmers felt that they should be compensated for their time on paperwork, and noted that compensation would encourage and enable program participation.

[In response to whether compensation for paperwork was needed] *If it's this one-time application, no. If it is routine reports, it should be baked into the cost that we get back.*

Compensation certainly helps, because in my case and a lot of farmer family cases, if it's like, oh, I have to do this during a time where I need to have childcare, but then I'm being compensated in a way that I can do this thing. I can't do it if it's not being compensated.

Shared Paperwork & Information Between Programs: Nearly 50% of farmers suggested that administrative work and farm records for a new PES program could be shared between and coordinated with existing PES and farm programs to ease the administrative burden and reporting redundancies for farmers participating in multiple programs.

[It would be helpful] if there could be a way to tie it into your NRCS paperwork or make it the same form you need for your organic certification, or just some way to integrate with the common programs that these farmers are already interfacing with and keeping records for.

[It would be helpful] if it's consistent deadlines and we soil test every year and if it's like, our soil test is going to our organics and the ecosystem services inspector. And I just know off-season that that's going to be due, instead of having all of these programs that have similar requirements but are all happening at different times of the year— that's burdensome.

I would think that would make the most sense if you make ease of entry as low as possible for farmers who are in existing programs to then branch into whatever program we were creating.

Data Privacy: The topic of data privacy was not explicitly prompted in the interviews, but several farmers acknowledged it as a consideration which might influence their participation in a program.

Where this data goes might affect my willingness to do administrative paperwork. "Who's going to own this data and how might it be used in the future or not?"

Exploring Payment Rates and Compensation Structures

Compensation Scenarios: Two different compensation scenario topics were discussed with farmers during the interview; compensation for maintaining high levels of soil health and compensation for enhancing levels of soil health. For each topic, farmers were asked for their preferred payment rate, as well as the minimum level of payment which they would be willing to accept.

1) Payments for *Maintaining* High Soil Health: In the first compensation scenario discussion, farmers were asked to think about a PES program where farmers were paid for maintaining high soil health on their farms. Farmers were asked to imagine that the program had a set threshold for specific soil health metrics, and if a farmer's soil health was at, or over, that threshold, the farmer could qualify for a payment. A specific organic matter percentage level based on their soil type, i.e., 4%, was used as an example. Farmers were told to imagine that their soil was already at or over that percentage and were then asked what they thought fair compensation would be for already being at that high level.

2) Payments for *Enhancing* Soil Health: In the second compensation scenario discussion, farmers were asked to think about a PES program where farmers were paid for enhancing soil health on their farms. Farmers were asked to imagine that the program had multiple payment tiers based on different pre-determined tiers/levels of soil health, each with a different payment rate. Those with soils in higher soil health tiers would receive higher payment rates. Farmers were told to imagine that their soil qualified for the lowest tier of soil health and would, therefore, receive the comparatively lowest compensation rate. To have higher payment rates, they would need to bring their soil health metrics up to the next threshold benchmark. Farmers were asked what payment rates would incentivize them to invest in improving their soil health enough to receive the next higher threshold payment rate.

Payment Rates: Farmers were asked to provide the preferred payment rates for both scenarios, as well as the minimum rate which they would be willing to accept. These questions were framed for consideration as if there was no associated administrative burden, to focus the conversation on compensation for performance. Many farmers had difficulty deciding on specific dollar values, and a few were unable or unwilling to give specific dollar values. Fifty percent of farmers with less than 50 acres had difficulty assigning dollar values to soil health compensation scenarios, and 36% of farmers with more than 50 acres struggled with this. Farmers frequently linked desired payment rates with what they would need to do to sustain or achieve soil health gains and the amount of investment it required. Average dollar amounts for each conversation topic provided by farmers are included in Table 3.

Suggested payment rates varied greatly across all farmer interviewees. Some trends between suggested payment rates and farm size (based on number of acres) were statistically significant. In both compensation scenarios, farmers with fewer acres tended to have higher preferred and minimum payment rates for per acre payment rate than those with more acres. When asked what level of payment would be meaningful to them at the whole farm scale (as opposed to a per acre scale), farmers with more acreage tended to cite higher amounts than farmers with fewer acres. The average whole farm payment rate that would be meaningful to farms under 50 acres was $3,523 /farm, whereas the average whole farm payment rate that would be meaningful to larger farms managing more than 50 acres was $15,604 /farm. Conversely, farmers with more acres cited lower per acre rates compared to smaller farms. The average preferred payment rate for maintaining soil health was $323 /acre among smaller acreage farms and $77 /acre among larger acreage farms (Table 3).

Table 3. Summary of compensation preferences reported by interviewees

	Average among farms < 50 acres in size	Average among farms > 50 acres in size	Average among all interviewees	p-value †	n
Preferred per acre payment for maintaining soil health	$323	$77	$186	0.14	18
Minimum per acre payment for maintaining soil health	$80	$18	$40	0.05*	23
Preferred per acre payment for enhancing soil health	$1,907	$134	$843	0.13	20
Minimum per acre payment for enhancing soil health	$803	$56	$269	0.16	14
Meaningful whole farm payment level	$3,523	$15,604	$9,322	0.07*	25

† T-tests evaluated significant differences between responses by farm size.
* denotes significant difference to p-value of 0.10
n is the number of interviewees who provided a dollar value number in response to each topic

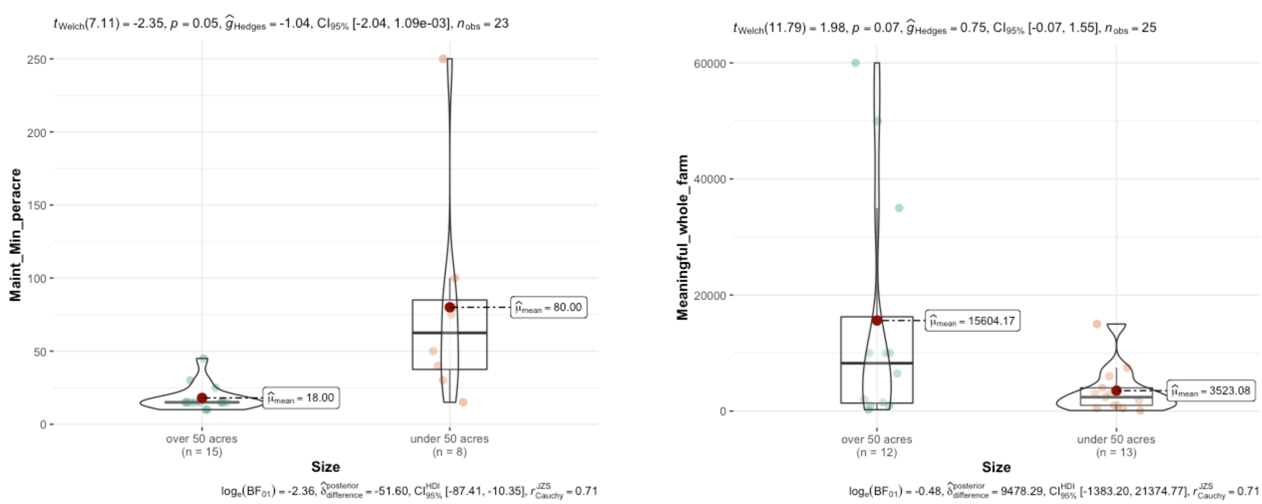

Figure 1. Boxplots and T-test results illustrate significant differences in compensation preferences that were observed between farms of different sizes.

Factors considered around payment rate for maintaining soil health: Many farmers had difficulty in providing specific dollar values, however most considered their current opportunity and direct costs in maintaining their soil health, (i.e., inputs, cover crops, rotations, equipment, and land taken out of production) when thinking about payment rates. Other farmers factored payment amounts by estimating what would be a meaningful additional source of revenue to their operation. Some farmers said they would be willing to take any monetary amount if there was no administrative burden on their end and program requirements aligned with current farm management, especially since most felt that soil health offered production value. Other farmers set minimum rates that they would be willing to accept, stating that their participation would be contingent on receiving a payment which meaningfully impacted the viability and financial wellbeing of their farm.

> *Any extra source of income, as long as you can handle the work required, is welcome, I would think, to the average farmer these days.*

> *I guess I would say that like 10% [of the] cost of input would be a meaningful compensation.*

> *I think if the goal of the program is really to incentivize high levels of soil health, and farmer effort to maintain it, then it ought to be a meaningful amount in the grand scheme of the farm operation. Enough that it might make a difference in the farm's ability to be profitable.*

> *I think that on the one hand, if there's costs to maintaining high, good soil health, but there's also benefits in that for our farm-- that is why we do it. We do it because we think that we're getting a better product.*

Factors considered around payment rate for enhancing soil health: Many farmers thought about the costs of equipment, practices, and other changes that may help them improve their soil health when thinking about payment rates in this performance-based compensation scenario. Interviewees found it difficult to pinpoint a dollar sign as they did not necessarily know what they would need to do to make those improvements. Farmers stated that payment rates would need to be high enough to motivate change, offer meaningful value, and make business sense. They often highlighted the potential difficulty and risk of making operational changes, and the uncertainty of outcomes. Farmers valued the idea of motivating positive changes and investments on farms.

> *It [appropriate payment rates] depends entirely on what sort of effort would be needed to reach that higher level. Is it a matter of timing, grazing, and harvesting a little differently, or manure applications, or are we talking about bringing in different amendments, or needing special machinery to somehow change management practices?*

> *To enhance, it's got to be enough to make someone want to do it.*

> *It [a payment rate] has to be based on something. So you [have] got to find the average cost, and then you give them some kind of extra over that to cover their cost, plus give them a reasonable extra incentive money.*

> *The disadvantage [of tier-based payments] is you could be investing a lot [to reach the higher tier] and maybe never get to that [higher tier] next year. But I think the advantages are you're really pushing people to actually do what's going to make a difference in soil.*

> *If you asked me right now how fast could I add a percentage point of carbon to all of our soil. A percent is a lot to gain. It [would] probably take five to 10 years…to gain a whole percentage point….unless we could do some really groovy cover cropping, no till stuff… Annual vegetables are hard because there's a lot of tillage.*

Payment Structures

Farmers were asked to consider the strengths and weaknesses of payments on a per acre basis, and payments based on tiers, or thresholds.

Per Acre Payments: 90% of farmers interviewed were in support of payments on a per acre basis. Most farmers easily related to and understood a per acre compensation structure— many already used a per/acre mentality to calculate potential revenue and the financial cost of their decisions. Some farmers also noted that per acre payments may be alluring to the large farms with potential for large environmental impact.

> *[Regarding per acre payments] I think that's the most straightforward way to do it. Most of the efforts are going to be on a per acre basis.*
>
> *I think that a per acre payment has a lot more transparency for me as a producer of, like, it's easy for me to conceive of I know what my per acre costs are and it's easy for me to conceive of what the payment, how it compensates for those costs. And my per acre production metrics and everything, just, we already think by the acre.*

Nearly half of the farmers noted that undifferentiated per acre payment rates across different farm types would favor farms with more acres and those which were less intensively managed. Some thought favoring farms with more acres was justified because they had greater potential environmental impact. However, there was general disquiet with how per acre payments might leave out smaller and more intensively managed farms. Numerous individuals suggested a minimum baseline payment for a farm plus per/acre payments to better and more meaningfully include smaller farmers in per acre compensation structure.

> *I can see a disadvantage of it being that if you're going to be compensating different types of farms across different production methods with the same for acre payment that that might be hard. Because dairy farmers have way more acreage, but are putting far less into each acre. Their cost of production or cost of input per acre is way lower.*
>
> *I think it [per acre payments] disenfranchises the smaller acreage farmer, but that said they're on less acres. So if the point is ecosystem services, the more acres you manage, the more impact on that ecosystem you potentially have.*
>
> *I'm a small, diversified vegetable farmer. I'm not managing several 100 acres, so my payment's going to be substantially lower than someone who's managing a large tract of agricultural land. That's [per acre payments are] a disadvantage to the smaller grower.*

Tier/Threshold Payments: Two thirds of interviewees supported the idea of a tiered-based approach for payments rates, with farmers providing higher levels of ecosystem service receiving accordingly higher payments. Farmers noted that meaningful increases in payments between tiers would encourage or enable them to make positive changes on their land— farmers liked the idea of incentivizing positive changes. It was, however, commonly articulated that payments would need to be high enough to incentive the change, especially if it involved making changes that farmers perceived as risky or extremely costly. Numerous farmers thought that incentivizing environmental gains and public benefits (or, at least, preventing of loss of public benefits or services) was important if there was public money involved. Some farmers vocalized appreciation for how setting certain tiers would act as some compensation for farmers who have already been doing good work for years.

> *I think setting thresholds and having a scale that people could move up would really possibly incentivize people to just continue growing healthier and healthier soil and learning about and implementing better farming practices, versus if it's just a set farm payment.*

> *[Tier-based payments] offers more of an incentive, I think, to continue improvement as opposed to a one-time thing of just saying, "Oh, okay. I'm level one. I like that. Thanks for the money," and then you don't do anything.*

Need to Consider Differences Between Soils, Farms, & Production Systems:

For a program paying for soil health, all farmers thought it was extremely important to make sure the program accounted for and considered inherent and inherited differences between farms and fields based on different soil types, management histories, and production systems. Many farmers said that the tiers should be nuanced and account for factors like soil types, historical land uses, farm type, and production methods. Some farmers highlighted some challenges around the potential difficulty and uncertainty in achieving and/or maintaining a desired or expected outcome. Farmers indicated that they were most interested in a program which had expectations and goals which were appropriate and achievable for their farm type, soils, economic circumstances, and management practices/goals.

> *You may have to do them by soil type, because if you have a sandy soil there's no way you're going to get a high organic matter…. that's got to be incorporated in there somehow.*

> *It's not necessarily fair to create a single threshold across all soil profiles, [or even] all similar soil types because historic management is a master factor in that… You'd be much better served—the farmers would be better served, the environment and the communities would be better served— by incentivizing farmers to increase organic matter and other soil metrics based on the exact characteristics of the soil that they've inherited as managers.*

> *Someone in a pasture-based system is probably going to have a lot higher soil health than someone in a tillage-based vegetable system. And what is a realistic expectation for those [respective] systems?*

Alternative Forms of Compensation: Without prompting, approximately 25% of farmers brought up alternative, non-monetary forms of compensation which could be valuable ways in which a program could support farmers including through access to equipment (i.e., seed drills or roller crimpers), supplies (i.e., soil amendments) or services (i.e., health care assistance). Over

90% of farmers were also interested in the value of farmer networking and learning communities, technical assistance, and/or the collection and interpretation of on-farm data. Some farmers also described the inherent value of soil health, and the way a PES program could provide information that would inform their efforts to enhance soil health.

> *I see incredibly high value in being able to understand more specifically in what areas we are improving and how, and then being able to compare some of the yield then benefits that are somewhat linearly connected to those improvements. And just to be familiarized with these newer technologies and these more in-depth analyses.*
>
> *Provide me technical equipment and access to technical experience to increase my crop yields through soil health— that's what matters.*
>
> *Technical assistance is not only obviously helpful, but I think in some ways it's motivating. If you're into one of these kind of arrangements and I, the farmer, are making that commitment, then knowing that I have these tasks or that these things are going on with my farm, which are all going to help me, is a motivator in itself to want us to stick with it and do well with it.*
>
> *I just want to say now maybe there's a different way of looking at payments. I don't know. Maybe it's more a matter of can we help you with something else? Well, healthcare is one, right? What kind of healthcare do many farmers, and how much does it cost them? Can they get Medicaid, Medicare, Green Mountain Care without having to worry about their income levels, you know?*
>
> *But then being able to really see what other people are doing and what their improvements are like, that's really valuable.*
>
> *I think the juicy carrots on the stick is the soil. If you have farmers enrolled in this program, you're already paying them to participate. If you are making meaningful, quantifiable improvements to their soil health, that would be payment enough, I think, for me. Because those improvements are going to translate to production improvements.*

Conclusion: This report provides a summary of interview responses around farmer perceptions of PES program administrative burdens, and different payment rates & compensation structures for a soil-health based PES program— the primary purpose of the interviews. However, the interviews produced additional rich findings and farmer insights. An extensive supplemental report of themes that emerged from the interviews was created as an appendix to this report, for readers who wish to do a in-depth exploration of farmer perceptions and suggestions for the design of a PES program. Please contact the authors of this report for a copy of the supplement.

Task 4 - Calculating the Full Economic Costs of Selected Field Management Change Scenarios for Improving Soil Health on Vermont Farms

Prepared by Dr. Jon Winsten of Conservation Performance LLC

Date: May 23, 2022

The goal of Task 4 is to estimate the full economic costs associated with the field management change scenarios to improve soil health on Vermont farms that were described as part of this project under Task 2. The scenarios are only meant to represent a very small subset of the possible field management changes available to Vermont farmer. They were selected to cover some of the more common types of changes for field crop production (Scenarios 1-3) and for vegetable production (Scenarios 4a-c). **Please see the Task 2 report for more details on the scenarios.**

The calculations and results for Scenarios 1, 2, and 3 are shown in the Excel file named "Task 4 Costs Scenarios 1-3". For Scenarios 4a, 4b, and 4c, these are shown in the file named "Task 4 Costs Scenarios 4a-c". This introduction provides an overview of the scenarios and the resulting cost estimates. When the information allowed for it, calculations of the cost per unit of soil health increase is presented, which can give an indication of the cost-effectiveness of the scenario to achieve improvements in soil health. Because the Working Group is focused on the Comprehensive Assessment of Soil Health (CASH), the cost-effectiveness is most useful when the CASH score is available for the baseline and scenario. The cost-effectiveness can also be calculated for other related metrics such as organic matter or aggregate stability, but these need to be interpreted with caution.

NOTE: The spreadsheet files are not intended to be decision support tools in which users can change values in cells to calculate results for other scenarios. In reality, the spreadsheets can be used to do this, but producing a ready-to-use decision support tool requires a level of formatting and instructions that are beyond the scope of this task for this project.

Scenario 1 – Best management practices for corn silage production

This scenario is based on specific research trials conducted by UVM Extension. The business-as-usual (BAU) is continuous corn silage with conventional tillage and no cover cropping. The scenario is the use of no-till and winter rye cover crop. The use of no-till saves the farm $50.50/acre, but the cover crop costs $85/acre to sow the seed and terminate the crop in the spring. There is a reduced yield of 3.3 tons/acre with the BMPs, which imposes an opportunity cost (i.e. foregone profit) of $132/acre. The overall result is a reduced profit of $166.50/acre for the BMP scenario.

The UVM research included scores for the Comprehensive Assessment of Soil Health (CASH), as well as other components such as organic matter and aggregate stability, each of which has been used to show the cost per unit of increase for this scenario. The CASH score increased by 5.40, which results in a cost of almost $31 per point. In a similar fashion, the scenario cost $55.50 for each 0.1% increase in the measured soil organic matter and $15 per 1% in aggregate stability.

Scenario 2 – From continuous corn silage to a rotation of 5-years corn silage and 5-years hay

This scenario is also based on research results from UVM Extension. See Task 2 report for more details. Based on the published crop enterprise budgets used, the profitability of producing hay is almost twice as great as for producing corn silage. However, many dairy farms have their feeding program based on the use of corn silage so this does not imply that dairy farmers should grow hay instead of corn silage. The economic cost of this scenario is difference in the average annual profit between growing corn silage continuously versus growing corn silage for 5 years and hay for 5 years. This difference is estimated to be $159 more profit for the corn-hay rotation.

Scenario 3 – From continuous corn silage to well-managed grazing

This scenario uses the same baseline of continuous corn silage which has an average profit of $230.90 per acre per year. As described in the notes on the Scenario 3 tab, to calculate a comparable profit per acre the annualized costs for pasture establishment are calculated. This includes costs for fencing, water system, seeding, and lanes. The calculation of each of these costs are described in the notes and can be seen in the Pasture tab of the spreadsheet.

Added to the establishment costs are the annual production costs to get total annual costs for pasture. The value of the pasture forage produced is based on the yield, the relative feed quality and the equivalent value per ton of hay on a dry matter basis. The estimated profit of well-managed pasture is $428 per acre per year, which is $197 more than for continuous corn.

Scenario 4a – Vegetable production with a soil building cover crop rotation

As can be seen in the Task 2 report, this scenario is based on research published by Idowu et al. The baseline scenario is a crop rotation consisting of beans, beets, sweet corn, cabbage, and beans. The soil conserving rotation is beans, field corn, clover/vetch cover crop, sweet corn, and beans. The full economic cost is represented by the difference in average annual profit per acre across these two rotations. The baseline results in an average annual profit of $2,191, which is $1,697 greater than the soil-building crop rotation.

The research did not calculate CASH scores (it predated the CASH test), but did indicate an increase in soil organic matter of 0.2 percentage points and aggregate stability of 5.1 percentage points (from 14.4 to 19.5%). This results in a cost of $247 per 0.1 percentage point increase in organic matter and $333 per 1 percentage point increase in aggregate stability.

Scenario 4b- Vegetable production with reduced tillage and cover crops

This scenario is also based on the Idowu et al. research results. The costs associated with the three tillage types are calculated separately from the costs of the two cover crop types; the combined costs for each combination is presented.

The improvement in soil health associated with each of the 9 combinations is not clear from the Idowu et al. paper. If the specific soil health improvements can be gleaned from the paper, the cost-effectiveness calculations for each of the 9 combinations of tillage and cover crops can be easily calculated.

Scenario 4c - Fertility practices in vegetable production

This scenario is based on research results published in Evanylo et al. (2008) from the Piedmont region in Virginia. There is no economic analysis in the paper; we have calculated the cost-effectiveness of fertility program with regard to the yield of corn, which is an indicator of the relative profitability of each treatment. Cost-effectiveness is determined by the cost of nutrients (fertilizer and/or amendments) per ton of corn yield (paper seems to use total biomass, which is fine as a measure of productivity). Using the information given in the paper, the poultry litter (PL) treatment was most cost-effective, followed by low-compost plus fertilizer (LCF), and then just fertlizer (F).

Related to soil health, Table 5 in Evanylo et al. shows results for bulk density, porosity, and water holding capacity. The treatments that showed the best results in these soil health metrics were annual compost (AC), biennial compost (BC), and biennial compost plus fertilizer (BCF). These results can be seen in the table in the spreadsheet titled “Relative change and rank of soil health metrics by treatment”.

The soil health results were combined with the relative profitability results to assess the relative cost-effectiveness of each treatment for improving each soil health metric. These can be seen in the table in the spreadsheet titled “Cost-effectiveness for Soil Health Metrics”. This analysis shows that PL was the most cost-effective for all three soil health metrics, followed by LCF, and F, and BCF.

The University of Vermont

Valuation of soil health ecosystem services

Vermont Payment for Ecosystem Services Technical Research Report #5

Version 2

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

July 2022

Contributors: Benjamin Dube, Alissa White, Heather Darby, Taylor Ricketts

GUND INSTITUTE FOR ENVIRONMENT

THE UNIVERSITY OF VERMONT EXTENSION

Valuation of Ecosystem Services from Improved Soil Health in Vermont

Contributors: Ben Dube, Alissa White, Taylor Ricketts and Heather Darby

Version 2.

Executive Summary:

- Soil health, and the practices meant to support it, can contribute to human well-being far beyond direct impacts on agricultural productivity.
- Ambitious improvements in soil health on Vermont farms could yield more than $31/acre/year in ecosystem services, providing a total value of $25 million/year across all Vermont agricultural land.
- Soil health improvements could increase carbon storage, nearly $19/acre/year in climate mitigation benefits.
- Soil health improvements would reduce phosphorus losses, yielding nearly $8/acre/year in water quality benefits.
- Soil health improvements would reduce erosion, yielding $2/acre/year in reduced damages to waterways.
- Soil health improvements would increase water retention and infiltration, yielding an average of over $2/acre/year in reduced flooding damages to downstream communities, with values over $10/acre in some locations.
- These estimates demonstrate substantial benefits which could justify serious policy efforts to support, measure and pay for soil health improvements on Vermont farms. The estimates are preliminary, and subject to many uncertainties.
- Ecosystem services generated from large improvements in soil health are similar to ecosystem services generated by adopting best management practices on annual cropland.
- This report focuses on in-field improvements in soil health, and thus does not include edge-of-field and whole-farm practices. The impacts of these other practices on ecosystem services are often better studied than those of soil health. We refer to this research below, but estimating their economic values is beyond the scope of this report.

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Introduction

For millennia, farmers have recognized the importance of soil health for crop productivity and resilience. Recently, scientists, policy-makers, and farmers have become interested in the non-agricultural benefits of healthy farmland soils. Healthy soils can support climate mitigation through carbon sequestration, protect the health of waterways by retaining nutrients and sediments, protect downstream communities by absorbing water and protect the air by regulating gaseous emissions. These and other ecosystem services provided by healthy soils may meaningfully contribute to the health and vitality of communities and ecosystems.

In recent years, farms have struggled financially and awareness of environmental problems have grown. Policy-makers worldwide have sought ways to compensate family farms for their environmental stewardship as a means to tackle both these problems. Farmers have organized under the banner of "regenerative agriculture" to experiment with new practices and promote values provided by healthy soils far beyond the farm.

Vermont is well-positioned to become a leader in this movement; family farming and environmental stewardship are central to our collective identity and economy. There have been several efforts to develop a policy framework for soil stewardship, but none have succeeded. In 2019, Act 83 of the Vermont Legislature created a working group to explore payments for ecosystem services as a framework for linking farm supports and environmental stewardship. This report was commissioned as part of this effort.

To design a program to promote soil ecosystem services, it is necessary to generate an estimate of the magnitude of each of the benefits. If we understand the scale and value of benefits, we can then judge the cost-effectiveness of such a program compared with alternatives, such as investments in other natural systems like forests and wetlands, or investments in hard infrastructure. Because improvements in natural systems can affect many different things we care about, putting total benefits in dollar terms helps us to combine different types of benefits and to assess which benefits are largest.

In this report, we present estimates for ecosystem services from soil health using two approaches for four different services. One approach generates estimates based on soil-health practices, and the other approach is based on improvements in soil-health indicators. For soil-health practices, such as adopting best-management practices on annual corn, we utilize a set of off-the shelf empirical models widely used to estimate ecological functions on farm landscapes. For soil-health indicators, we make estimates by linking these tools with soil data and statistical models describing how soil-health parameters influence the interaction of soils with water and their environment. We provide rough monetary estimates of the value of these services, using several different standard ecological economics methods. These results are necessarily rough but can help to elucidate the relative magnitudes of different types of benefits.

Scope

This report provides a preliminary valuation estimates for four important ecosystem services in the state of Vermont from soil health improvements, including carbon storage, phosphorus (P) loading reduction, erosion control, and flood mitigation. The report also briefly addresses impacts of soil health on nitrogen cycling and pollution, but complexity and uncertainty prevents us from estimating values. While soil health has numerous benefits to yield, crop quality and climatic resilience for the individual farmers and landowners, these benefits are outside of the scope of this report. Instead, we focus on public goods provided to society at large, to inform a potential PES scheme for soil health in Vermont.

In keeping with the mandate of this project to focus on soil-health, we have excluded other management and land use changes that could have large impacts on the same ecosystem services. These include wetland restoration/construction, forested riparian buffers, conversion of agricultural land to forest, artificial ponds and stream de-channelization. While these “edge-of-field” or “whole-farm” strategies may have large impacts on the ecosystem services of interest, they are not directly “soil-health” related. The impact of these interventions on ecosystem services is also better-studied than the impact of soil health. A full assessment of the potential of farms to provide ecosystem services should consider impacts of all potential management options, but these are beyond the scope of this report.

Overall methods

This report estimates ecosystem service provision using two distinct perspectives (Figures 1,2). First, we estimate the increase in ecosystem services from ***soil health practices***, using the scenarios developed for Task 2 of our technical services contract to the PES Working Group as examples. See Table 1 for more details of these practices. For this, we use an array of existing empirical models, including the Universal Soil Loss Equation, the Curve Number Method and the Vermont Phosphorus Index to estimate the change in ecosystem services. All these scenarios take row crops with conventional tillage as their baseline for comparison. These methods assume a “normal” soil-health condition.

Table 1: Descriptions of Soil Health Practice Scenarios used in this Report. Row crops with conventional tillage was used as the baseline for comparison.

Soil Health Practice Scenario	*Description*
Corn BMPs	No-till / zone-tillage, winter rye cover crop & manure injection. These represent heavily-promoted BMPs by the state of VT for water quality.
Corn-Hay Rotation	Replacing Continuous Corn with a rotation that is half-corn, half-hay without implementing the BMPS mentioned above
Permanent Hay	Long-term perennial hay crops.
Pasture	Long-term perennial pasture[1].
Vegetable BMPs	Annual vegetable production with greatly reduced tillage with both winter and summer cover crops. This scenario uses vegetables grown conventional-tillage and no cover-crop as its baseline.

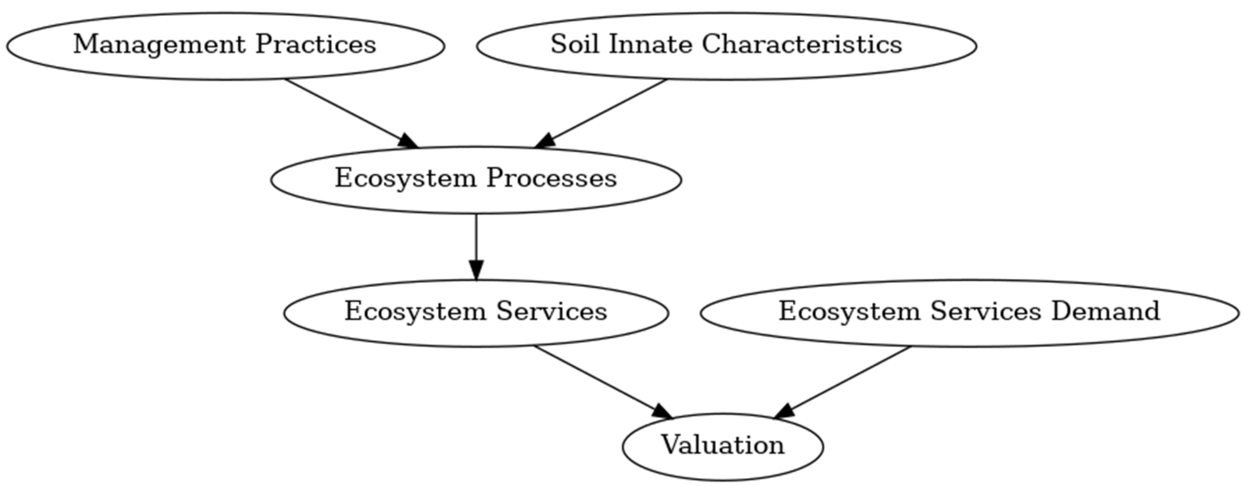

Figure 1: Conceptual Model for Estimating Impacts of Soil Health Practices on Ecosystem Services.

[1] We do not attempt to model or define different pasture management styles, which may have very different impacts. If careful pasture management has large impacts on ecosystem services, it will be due to improve soil health, and the benefits would best be reflected through estimating the direct impacts of soil-health.

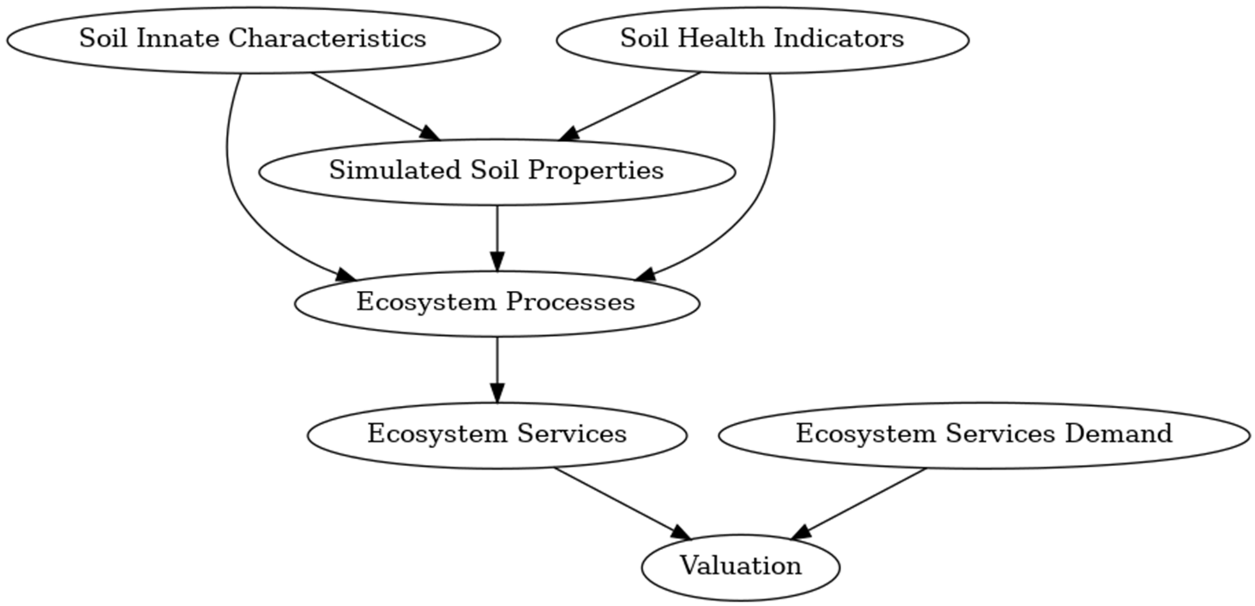

Figure 2: Conceptual Model for Ecosystem Services Assessment of Soil Health *Indicators*

Second, we estimate impacts of changes in **soil-health *indicators*** on ecosystem services. We use data from the NRCS Soil Characterization Database (Reinsch & West, 2010) to define innate characteristics and reference conditions for Vermont soil series. Innate characteristics are those that don't change with management, such as soil particle-size distribution. Reference conditions are used as typical baselines for conditions that are potentially impacted by management, such as Soil Organic Matter, Bulk Density and depth of each soil horizon. Soil innate characteristics and soil health indicators are used to simulate other soil properties, such as soil erodibility, plant available water capacity and saturated hydraulic conductivity. These parameters are then used to simulate changes to the ecosystem services of interest, using similar tools to those used for soil indicators.

We present two scenarios for moderate and large changes in soil-health and estimate their impacts relative to the reference state of the soil.

These soil health scenarios are:

"Best": Soil Organic Matter in the A horizon is 50% higher than the reference condition and bulk density 20% lower.

"Good" : Soil Organic Matter in the A horizon is 25% higher than the reference condition and bulk density 10% lower.

For each scenario, we simulate these changes on 10 different common agricultural soil-series: Tunbridge, Winooski, Agawam, Windsor, Covington, Vergennes, Cabot, Hadley, Hamlin and Georgia, and present average results, sometimes grouped by soil characteristics.

Bulk Density and Soil Organic Matter are important indicators of soil health, but their impacts on many important ecosystem processes, and therefore ecosystem services are mediated through their impacts on *other soil characteristics*. Many of these other soil properties can, in principle, be measured, but would not be feasible to include in a PES program. Instead, these characteristics, including plant available water capacity, porosity, saturated hydraulic conductivity and soil erodibility are simulated through a series of pedo-transfer functions[2]. These equations are used to estimate unknown soil properties based on known soil properties.

In this report we estimate the impacts of two different improvement scenarios for several different common Vermont Agricultural Soils and present averages of these results. The two improvement scenarios are the “high” scenario: Soil Organic Matter increases by 50% and bulk density declines by 20% and the “medium” scenario: SOM increases by 25% and bulk density declines by 10%. In both scenarios, these improvements are confined to the upper layer (A horizon) of the soil, and the decrease in bulk density is compensated for by increasing the depth of the A horizon to keep the mass of soil in the A horizon constant. For reference, agricultural soils in Vermont have average SOM contents of roughly 4.3% and bulk density of about 1.35, with substantial heterogeneity across soil types. This average soil would see SOM increase to 5.4% or 6.5% and its bulk density decrease to 1.22 g/cm^3 or 1.08 g/cm^3 in the good and best scenarios, respectively.

Additional information about the scenarios can be found in Appendix 1.

Importantly, we do not attempt to merge these two approaches and estimate the impact of soil health practices on soil characteristics themselves, and then the impacts of these soil characteristics on ecosystem services. We hesitate to do this because most tools used to assess the impact of practices on soil ecosystem functions and services do not allow us to partition between their *direct* impact on soil ecosystem services and their impact which is mediated through soil health. For instance, the NRCS Curve Number method predicts lower runoff from land that is in permanent grassland than land that is growing corn. This is due to improved soil health, greater vegetative cover and other differences, but the method gives us no way to disentangle the portion of the impact that is due to soil health itself. Hence the two distinct approaches described above.

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[2] A pedo-transfer function is an equation that predicts an unknown soil property based on several known soil properties. For instance, if we know the texture of the soil, (as % sand, % silt and % clay), its bulk density and its soil organic matter content, what is the expected plant-available water capacity?

Results Summary

Overall, improvements in soil health and adoption of soil health practices have the potential to produce substantial benefits for Vermonters and people around the world. Below we summarize the results of our valuation estimates for each service.

Carbon storage benefits are substantial, valued at $18.84/acre/year in the “best” scenario, and $9.42/acre/year in the “good” scenario. We calculate these based on the reduction in warming each year due to reduced atmospheric carbon.

Flood mitigation benefits have the lowest valuations, but also the most spatially variable. Average values are roughly $2.73/acre/year for the “best” scenario and $1.10/acre/year for the “good” scenario. These values are relatively low largely because farmland in Vermont is commonly situated low in watersheds, and therefore has protects relatively fewer downstream areas compared to other runoff-generating land cover types. A small minority of farm fields have many downstream communities at risk, and those fields have potential flood-mitigation values that are 5x or 10x higher.

Erosion reduction benefits are also relatively small for most farm fields- $2.47/acre for the “good” scenario and $1.21 for the “best” scenario. These benefits are proportional to the scale of current erosion losses; fields that are flat and already have extensive soil-cover will have much smaller reductions than steeper fields or those currently in row-crops.

Phosphorus retention benefits are large in dollar terms but come with much uncertainty. Average values for the “good” scenario are $4.12 /acre/year, while average values for the “best” scenario are $7.87. The relationship between reduce soil health and P-loading loading from soils with pattern tile drainage or other direct sub-surface connections to surface-water is more complex, and this report does not draw conclusions about this. Like erosion, P-mitigation benefits from improvements in soil health are highest where potential for P loss is highest, and in watersheds where P loading is a larger problem.

Beyond the four ecosystem services we were able to value, two more deserve mention:

Nitrogen retention benefits are difficult to characterize because nitrogen can leave farm fields and damage the environment through many pathways, and practices and soil conditions that reduce one pathway may increase another. We present general estimates of the magnitude of harms from N losses from Vermont farms and demonstrate that these harms are large enough that moderate mitigation would generate substantial benefits.

Soil biodiversity benefits could be valued in several ways, but producing a monetary valuation was beyond the scope of this report.

Under the "best" scenario of soil health improvement, we estimate that farms could be credited with providing an average of $31/acre/year worth of combined ecosystem services (Figure 3). Under the "good" improvement scenario, farms could be credited for $16/acre/year. In our analysis using soil health practices (Figure 4) estimates, all management improvements from a baseline of continuous corn with normal practices create total values of at least $25/acre/year.

Table 2: Summary of Ecosystem Services Valuation of Soil-Health Improvements for two Scenarios and 4 Services.

	Valuations ($/ac/yr)			*Physical Quantities*		
Service	*Good*	*Best*	*Valuation Rate ($/unit)*	*Good*	*Best*	*Units*
Carbon Storage	**$9.42**	**$18.84**	**$1.44**	**13.1**	**6.5**	**Tons (US) of carbon /acre.**
Flood-Runoff Mitigation	**$1.10**	**$2.37**	**$8.40**	**0.28**	**0.13**	**Inches / large storm**
Erosion Reduction	**$2.29**	**$4.56**	**$11.20**	**0.20**	**0.41**	**Tons (US) /acre/year**
Phosphorus Retention	**$4.12**	**$7.87**	**$56.82**	**0.07**	**0.14**	**Lbs / acre /year**

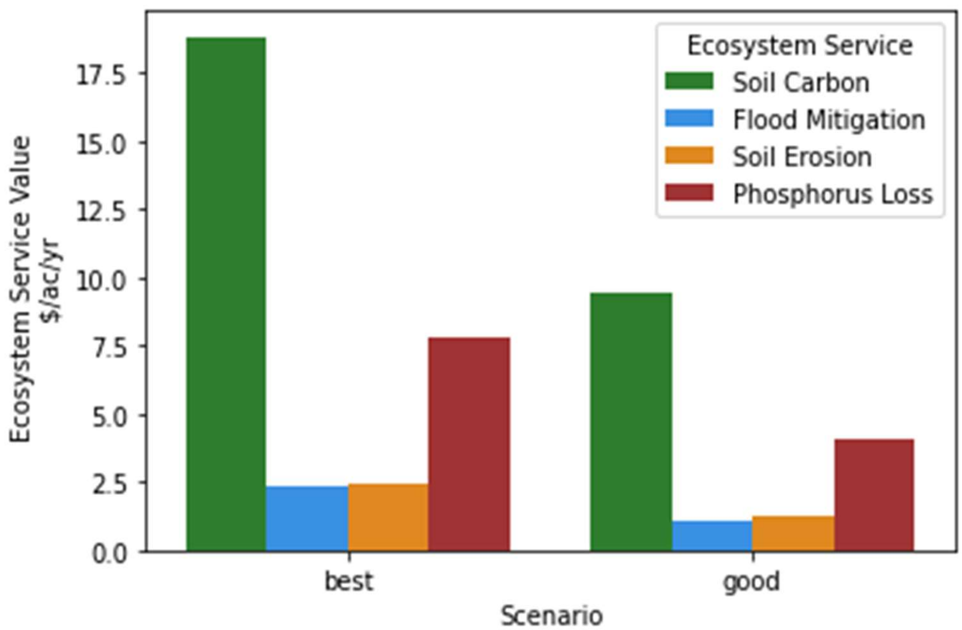

Figure 3: Predicted values of Improved Ecosystem Services resulting from Two Soil-Health Improvement Scenarios. Best: 50% increase in SOM and 20% decrease in bulk density. Good: 25% increase in SOM and 10% decrease in bulk density.

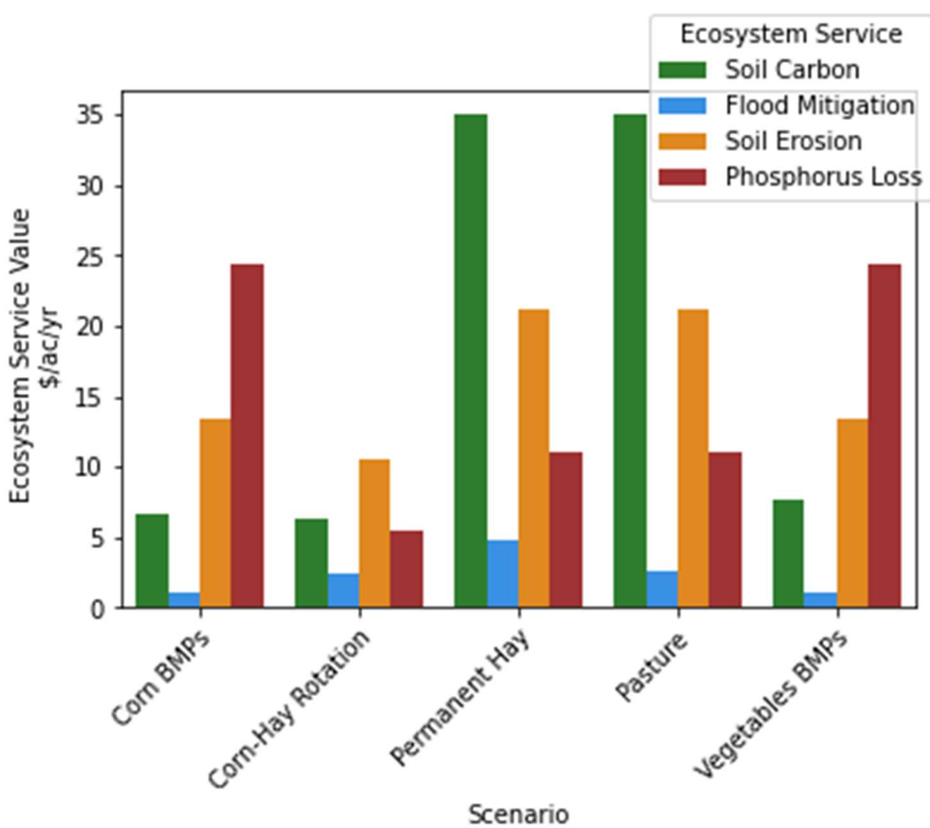

Figure 4: Values of Improved Ecosystem Services resulting from Changes in Soil-Health Practices. Practices match those developed in for Task 2. See Table 1 for descriptions.

Detailed methods and results for each ecosystem service

CLIMATE REGULATION

Healthy soils can mitigate climate change by storing carbon that would otherwise be in the atmosphere. Additionally, soil health and soil health practices can influence the production of other greenhouse gases from soils, especially methane and nitrous oxide.

Globally, soils hold an enormous amount of carbon; 3-4 times as much carbon as is currently in the atmosphere (Lal, 2003). Increasing the carbon content of soils may be an efficient way to mitigate climate change. Voluntary and regulatory markets for carbon storage make carbon storage by far the most commonly marketed ecosystem service from agriculture and other land-uses. Payments for land use-based carbon offsets now reach $1 billion / year (Dunn, 2021). Because soil carbon is directly measured as a soil-health indicator, there are fewer elements of uncertainty in the relationship between the soil health metrics and the ecosystem services of interest.

Valuing Carbon Storage and Carbon Accumulation:

There are two general approaches to valuing carbon sequestration. First, we may multiply the carbon sequestered by an estimate of the Social Cost of Carbon, as calculated by the EPA, other government agencies or academic researchers. The EPA's social cost of carbon for the year 2021 is $51/ton of CO_2 (Interagency Working Group & others, 2021). This would be equivalent to $186/ton of soil organic carbon. Alternately, we may compare them to the prices paid by voluntary or compliance-based offsets markets or other corporate programs. The Boston-based Carbon-Offset start-up Indigo Ag (Indigo Ag, 2022) currently guarantees prices in range of $10-$15/ton of CO_2, while the company Nori allows farmers to sell offsets for $15/ton (*Nori Carbon Removal Marketplace*, 2022). $15 per ton of CO_2 is equivalent to $53 for each ton of organic carbon added to farm fields. *We link values to the price of offsets ($15/ton) rather than the social cost of carbon because there is little way for Vermont government to capture the benefits of the globally avoided climate damages accounted for by the social cost of carbon*. To account for these global benefits, the values can be multiplied by 3.4.

A major area of concern for carbon sequestration payments is permanence. If a company pays for a carbon offset, or a government pays to reduce damages from carbon, that payment assumes that this carbon is permanently removed from the atmosphere, or at least removed for many decades. If this soil carbon is instead released back into the atmosphere, only a small proportion of these damages would be averted from the short-term storage of carbon, and the value of the carbon storage is greatly reduced.

Most carbon-offset programs deal with this difficulty by enforcing contracts on farmers, obligating them to continue their climate-friendly farming practices. This option seems unlikely for a state-run PES program. Some offset-generating carbon sequestration programs assume that not all carbon will be permanently stored and may reduce payments accordingly[3]. This approach could be taken by a soil PES program. Another approach could be to subtract the value of carbon losses from payments to the farmer generated by other ecosystem services. For the valuation of carbon storage from *practices*, we use a 50% withholding rate, such that farmers are only paid for 50% of the carbon they are expected to accumulate in their fields.

For soil-health indicators, and soil-health practices we must estimate slightly different values for carbon benefits. For practices, the benefits are usually measured in *carbon accumulation, in tons / year* with a change of practices. These rates of accumulation are expected to be maintained for a certain period of time (e.g. about 10 years) after transition in practices, before soil organic carbon contents stabilize at a new, higher level. For soil health indicators, soil organic matter is measured in *tons of carbon*, as a quantity. Because of this, if we measure the value of higher soil carbon using the social cost of carbon, or the sales price of offsets, we get a single lump-sum value. Not only is the number not comparable to the other values generated in this report, but impermanence and small measurement errors on farms with stable soil carbon could frequently generate substantial negative values[4].

To deal with these issues, we annualize the social cost of carbon and estimate the benefits generated by storing a ton of carbon for one year. To do this we utilize two different methods and average the results. In one method, we do this using calculations for the social cost of additional heat or "radiative forcing." In the other, we calculate a perpetual ongoing payment that is equivalent to the social cost of carbon.

The average of these two methods is $1.44/T SOC. This is valuation can be thought of as a "temporary rental" carbon offset, as opposed to a "permanent sequestration" carbon offset. Because these values are for climate mitigation benefits realized *each year,* no reduction is made to the valuation due to impermanence.

More information on this method, and its justification, can be found in Appendix 2.

Estimating Physical Quantities:

For Carbon Storage based on practices, we use estimates from the research literature compiled during Task 2. For Carbon Storage based on soil health indicators, we simply use the additional carbon in the simulated soil layers.

[3] The California carbon market has about ¼ of forest-based credits withheld in a "buffer pool", which may not be sufficient. (Badgley et al., 2022; Herbert et al., 2020). In this instance, landowners have signed binding contracts to continue land management, which is unlikely in a PES program.

[4] See Appendix 2 for an explanation of these concerns.

Results:

Figure 5 estimates annualized increases in soil organic carbon, per acre, per year, for the soil health practices scenarios. These results are presented grouped by soil-texture class, which is the largest influence on how much carbon a soil can hold.

Figure 6 shows the estimated total soil carbon storage increase for the soil-health indicator scenarios. Because the soil-health indicator scenarios include carbon as a state variable, we cannot use them to estimate annual rates of accumulation.

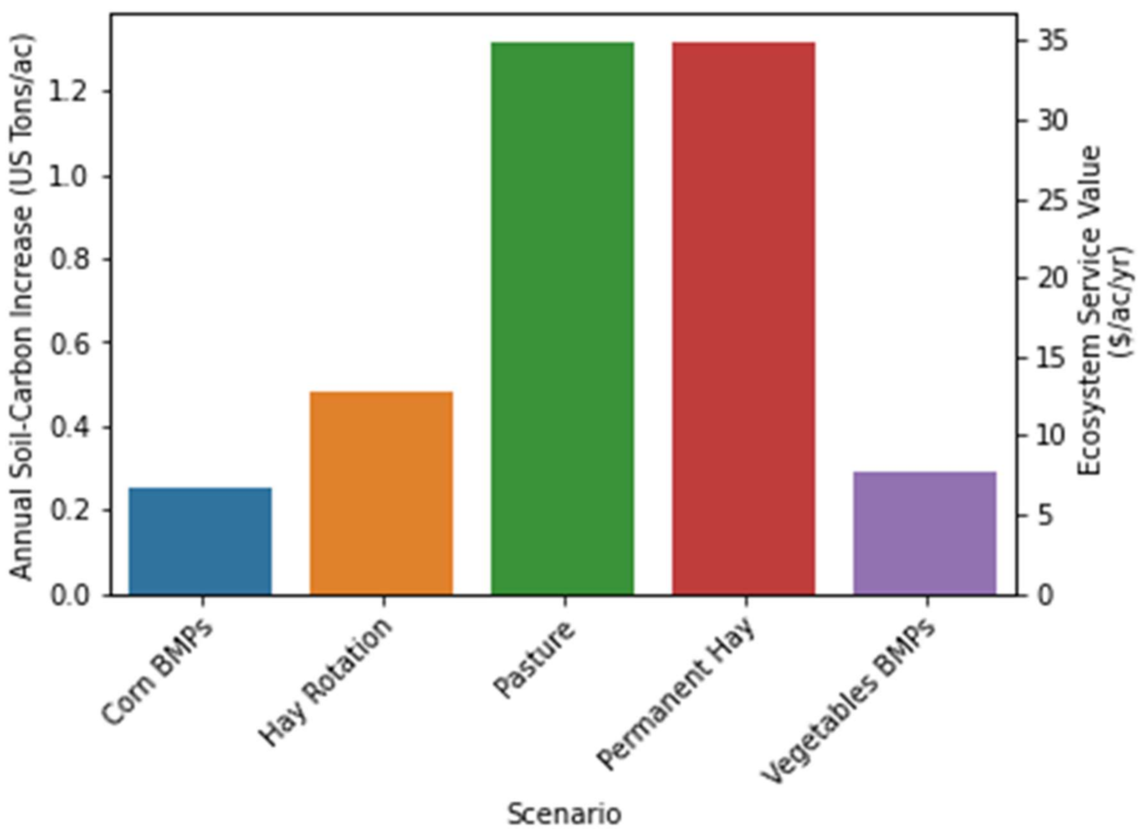

Figure 5: Total Increase in Soil Carbon and Ecosystem Service Value by Soil Health Practice Scenario[5]. Left axis reports predicted annual accrual of soil carbon, and right axis reports the economic value of these changes.

[5] Note that the Corn to Corn-Hay Rotation Numbers demonstrate the lack of durability in Soil Carbon increases: 5 years in Hay increases Soil Organic Matter dramatically, but almost half of that increase disappears when the field is rotated back into Corn for 5 years.

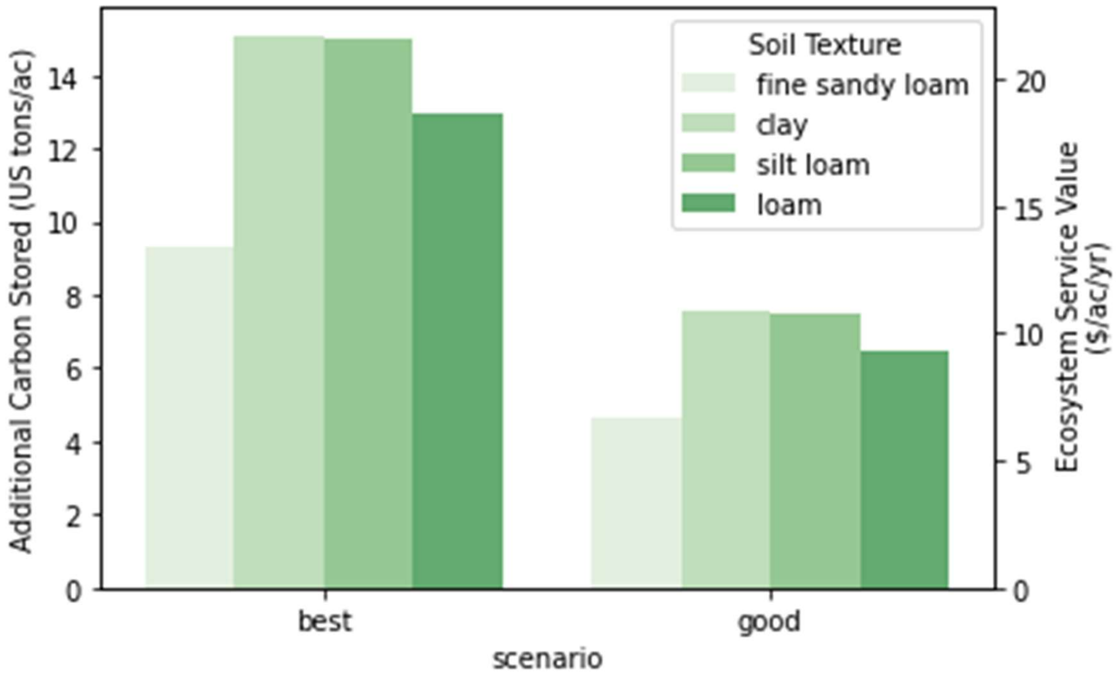

Figure 6: Total Increase in Soil Carbon by Soil Health Indicator Scenario, and Ecosystem Service Value. Left axis reports additional soil carbon stored, and right axis reports the economic value of these changes.

Variation of Service Provision and Values:

Because climate change is a global problem, the value of carbon storage is the same no matter where it is stored. For the quantity of carbon stored, farm fields with finer textures, such as clays, have more carbon storage capacity than coarse-texture soils such as sandy loams.

Caveats and Areas for Future Work:

While we have not completed more detailed simulations, in general, increased SOM results in moderate reductions in CH_4 emissions, while decreases in bulk density can moderately reduce emissions of N_2O. In temperate cropping systems, N_2O emissions are often quite substantial, especially in systems with substantial N inputs from fertilizer, legumes, or livestock manure. Methane emissions from soils, however, are relatively small, highly variable, and even sometimes negative. We discuss the general magnitude of N_2O emissions in more detail in the section on nitrogen losses.

For soil-health practices, the saturation of soil carbon-holding capacity is an important issue. The valuations provided for practice / land-use changes are only applicable for the first 10-15 years after converting from conventional corn and may not be applicable where farmland was recently converted into conventional corn.

Edge-of-Field and Whole-Farm Interventions:

Though beyond the scope of this report, a PES program compensating for carbon sequestration on agricultural land could also incorporate payments for carbon stored in woody biomass. Eligible land-uses might include silvopasture, riparian buffers, farm woodlands and other agroforestry.

FLOOD RUNOFF MITIGATION

Since the devastating flooding during Tropical Storm Irene in 2011, Vermonters have been working to make our communities safer and more resilient to flooding. Climate change is expected to increase the frequency of severe storms in Vermont, making this work even more important. Soils and vegetation upstream can play an important role in buffering peak stream-flows during storm events, protecting people, homes, and infrastructure in the valleys below. Farm fields also play an important role in protecting communities by providing space for rivers to spread out and slow down during flooding events. Flood-control services provided by coastal wetlands, riparian wetlands and upland forests are well-studied, but comparatively little research has been done on the impact of soil health in agricultural fields on flood risk[6] .

Our estimates attempt to be inclusive of all damages done by flooding, but estimates of damages, especially indirect damages, are highly imprecise. The estimates of flood-mitigation services attempt to fully account for increases in the ability of soils to infiltrate and hold both rainfall and floodwaters which inundate them but may not comprehensively account for the later.

Valuing Flood Risk:

To value reductions in flood risk from soil health practices and indicators, we must ask several questions:

- First, *what is the total, annual value of Vermont's flood risk (in $)?*
- Second, *what proportion of this risk can be attributed to runoff from agricultural land use (in %)?*
- Third, *how much of a difference does reducing runoff by a given amount reduce that runoff (in acre-inches for a reference storm)?*

We separately estimate these values for generational floods (>50 year recurrence interval) and more-frequent large floods, (10-25 year recurrence intervals). A summary of the steps that we took can be seen in Table 2.

[6] For a review of research on soil compaction and flooding, see Alaoui et al (2018), for one of soil health practices and flooding, see Basche (2017).

Table 3: Steps Taken to Estimate Flood Protection Values of Abating Agricultural Runoff

"Generational Storms"	**Number**	**Derivation**
Damages	$1 billion	TS Irene was about $1 billion in USD 2020
Frequency	50-year	TS Irene is a roughly a 100-year return time. We account for other large storms (e.g. 1973, 1938) by halving this.
Value of Risk	$20 million / year.	$1 billion / 50
Agriculture's Contribution	5%	Agricultural Land contributed 4.6% of damage-weighted runoff and was 5.6% of the landcover upstream from damaged communities (weighted by federal assistance).
Value of Agriculture's contribution	$1 million /year	5% of $20 million
Climate Change Adjustment (next 30 years)	50%	Estimates include: Wobus et al (2014) (+30% in $ damages, US) Gourevitch et al (2022) (+148% $ damages, VT, next 100 years) Swain et al (2020) (+30-127% people at risk US). These increases are driven by both larger and more-frequent storms.
Estimated value of runoff abatement (50 year flood or greater)	$0.88/acre-inch/year	$1 million * 1.5 / 1.7 million acre-inches of runoff from agriculture during Irene.
10-25 Year Floods	**Number**	**Derivation/Notes**
Damages to buildings in Champlain Basin:	$25.5 million /yr	Annualized Damages of 10 & 25 year floods from Gourevitch et al (2021)
All damages in VT	$72.9 million /yr	25.5 / .7 / .5 70% of VT structures are in Champlain Basin, about 50% of flood damages are to structures.
Damages when soil is not frozen	$56.9 million	78% of 56.9 22% of Flood Insurance claims are for damages from between December 1st and March 20th.
Agriculture's Contribution	9%	Agriculture is 9.5% of the landcover above communities damaged by non-Irene large floods (weighted by payments to towns by FEMA). It makes up a smaller proportion of runoff, though the exact proportion is not clear.
Value of Agriculture's Contribution	$5.1 million / year	9% of $56.9 million
Adjustment for Climate Change	$7.68 million / year	5.1 times 7.68. Increase 50%, as above
Estimated value of Agricultural Runoff Abatement: (10 or 25 year flood)	$7.68 / acre-inch	Assume average agricultural runoff from more-frequent storms is 1 ¼ inch per acre, yielding 1 million inches of runoff from 800 thousand acres of crops, hay and pasture.

Documentation of the flooding damages to Vermont communities from Tropical Storm Irene are useful in determining the risks posed by other extreme flooding events. Tropical Storm Irene resulted in an estimated $733 million in total damages[7], $860 million in 2020 dollars. This estimate appears to include nearly $400 million in damage to transportation infrastructure, >$10 million in damages to agriculture and $130 million to rebuild the state government complex Waterbury (VT Emergency Management, 2018). Damages to private real estate likely exceeded $150 million, and include nearly $29 million in damages assessed by FEMA and nearly $43 million in claims to the national flood insurance program (Federal Emergency Management Agency., 2021), though these are likely only a fraction of total damages to private property[8]. We account for non-financial losses from flooding (loss of life, disruption of work and school, etc) by rounding this number up to $1 billion, though a higher number may be justified. Vermont sustained one other storm of this scale in the last 100 years, in 1927, and two other, somewhat smaller major flood disasters, in 1938 and 1973.

How much does Agriculture Contribute to Flood Damages from Runoff?

Based on the National Land-Cover Dataset, 14% of Vermont land is in agriculture: cropland, hay, pasture and orchards. This land is larger located in places with lower value for flood run-off mitigation, due to lower elevation. This lower-elevation land has lower flood mitigation value due to:

1- Lower rainfall at lower elevations.

2- Fewer people and structures downstream. A large proportion of farmland is very close to Lake Champlain or the Connecticut River. Figure 7 shows that the highest concentration of farmland is in areas that flow directly into Lake Champlain, and within each sub-watershed, the largest concentration of agricultural land tends to be below the most heavily-populated areas.

An estimate using the Curve Number Method[9] yields about 10% of total run-off from agricultural lands during Hurricane Irene (Figure 8). This runoff largely occurred in areas below the most-impacted communities. Weighted by total Federal Assistance money from Irene (Vermont Public Radio, 2013), the average Irene-damaged community in Vermont had 5.6% agricultural landcover in its upstream watershed, and 4.6% agricultural runoff. Based on a 50-year return time, $1 billion damages and a 5% contribution of agriculture to damages, the annual value of agricultural runoff from generational storms is roughly $1 million/year. Adjusting 50%

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[7] The Irene Recovery Report (Rose & Ash, 2013) estimates $850 million in total assistance paid out.

[8] The NFIP claims database holds 1009 claims made on Irene in VT, while the Irene Recovery Report estimates 3500 homes and businesses damaged/destroyed and the State Hazard Mitigation Plan estimates ~5000. Assuming that 24% of damages were covered by the NFIP yields ~$180 million in damages to real estate.

[9]The NRCS curve number method is an empirical model which uses land management and soil hydrologic group to predict the rainfall-runoff relationship for a location. We additionally use an adjustment factor for slope developed by Arnold et al (2012). The CN Method is still state-of-the-art for runoff estimation, it is one of two options used for estimating runoff in the Soil and Water Assessment Tool (SWAT) and the Agricultural Policy Environmental Extender (APEX). For more information, see: https://acwi.gov/hydrology/minutes/nrcs_cn_method.pdf

upwards for climate-change risks and allocating among 1.7 million acre-inches of agricultural runoff during Irene yields $.88/acre-inch/year in large-storm runoff.

Agriculture plays a larger role in more-frequent floods. The methods for calculating its impact can be seen in the second part of Table 3. For medium-sized flood-events, we use estimates from Gourevitch et al (2022) for impacts of 10-25 year floods. This study utilized probabilistic simulation modelling of flood events in the Champlain Basin at different recurrence intervals. They estimate annualized damages of $25.5 million from storms of this scale. This number is increased to account for buildings outside the Champlain Basin and non-building damages, then decreased by 22% to account for winter flooding. Among smaller storms that still received federal disaster declarations, the average flood-damaged municipality (again, weighted by disaster assistance) in Vermont had 9.5% agricultural landcover upstream. Adjusting slightly down to 9% accounts for lower runoff from agricultural land yields $5.1 million/year in agriculture-related flood damages. Multiplying by 1.5 for climate change, and assuming an average of 1.25 inches average agricultural runoff yields $7.68/acre-inch in flood mitigation services.

More details on the methods used for valuation, their justification and uncertainty, can be found in Appendix 3.

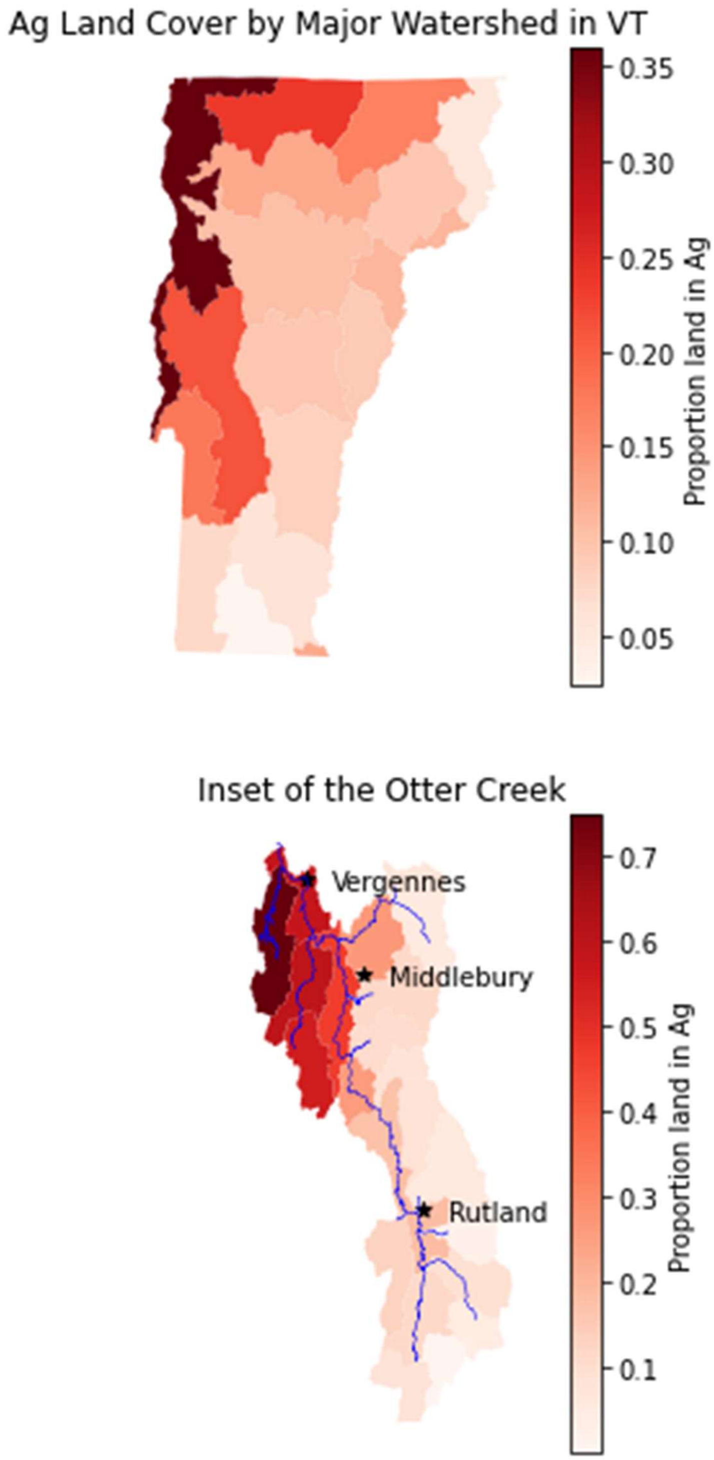

Figure 7: Percentage of Land in Agricultural Land Cover in Vermont Sub-watersheds. Data from 2014 NCLD. Agricultural land-use in Vermont is primarily close to Lake Champlain. 20% of agricultural land in VT is in sub-watersheds that flow directly into Lake Champlain.

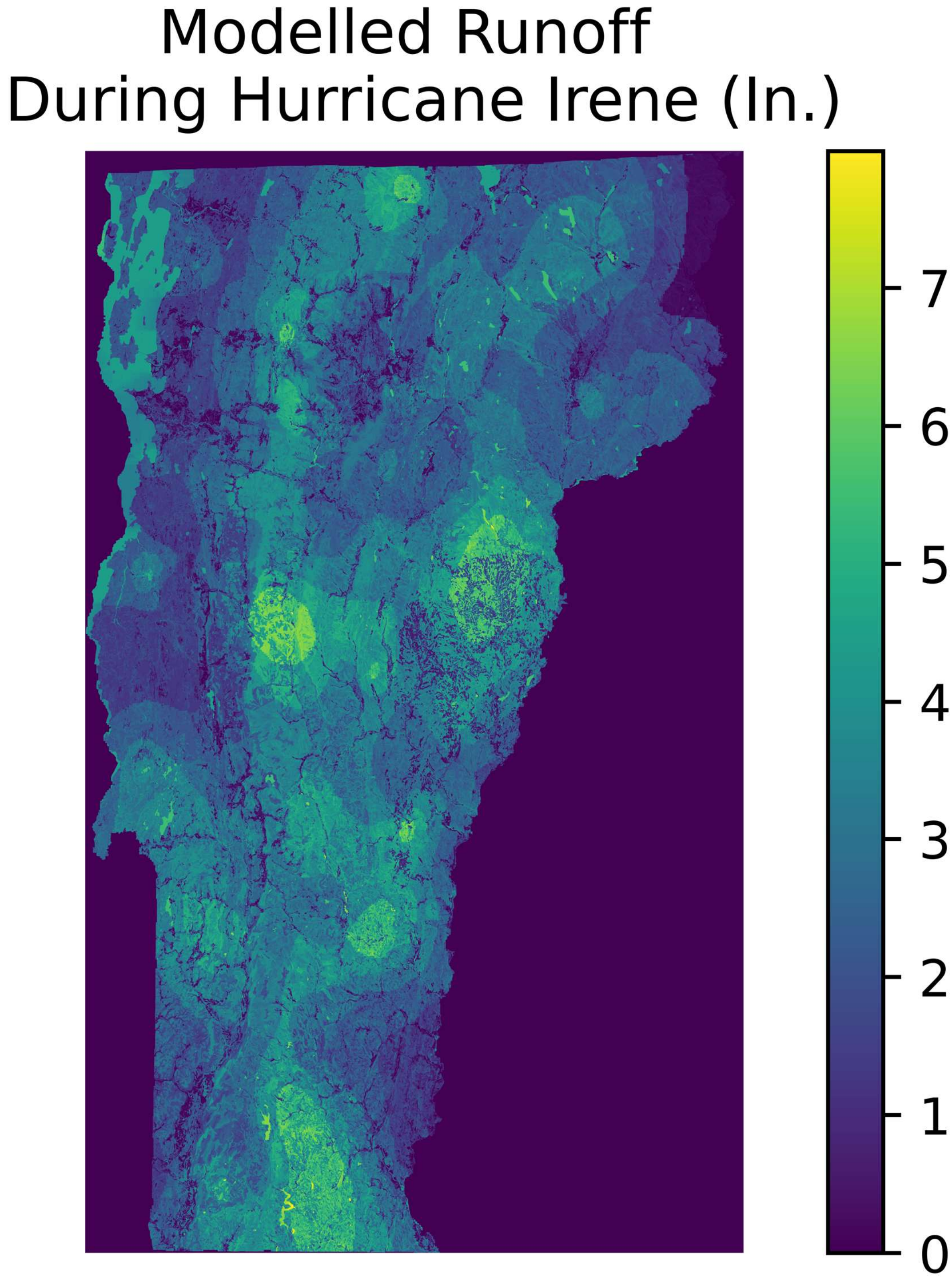

Figure 8: Runoff During Hurricane Irene, Modelled Using the NRCS Curve Number Method. Most runoff was generated from areas high in watersheds, with less agricultural landcover.

Estimating Physical Quantities:

To estimate runoff volumes for our analysis we simulate two different storms; a generational storm with 4 inches of rain falling over the course of 8 hours, and a large storm with 1.5 inches of rain falling over the course of 3 hours.

For reductions in runoff from practice changes, we use the Curve Number Method to estimate runoff volume. For very large storm events, this method is known to under-estimate runoff volumes, and thus likely exaggerates the impacts of practices.

For reductions in runoff from soil health, we use different methods for calculating flood runoff mitigation, based on soil hydrologic group. For soils in hydrologic groups C and D, we use a three-layer implementation of the Green-Ampt equation[10], while for soils in hydrologic groups A and B, we use an excess water-holding capacity method. Runoff from soils in hydrologic groups C and D is dominated by infiltration-excess runoff (runoff is generated when rainfall exceeds the soil's infiltration rate), which is well-simulated by the Green-Ampt equation. Runoff from soils in hydrologic groups A and B is dominated by saturation-excess, where runoff occurs when soils are filled to capacity. This is better simulated by available water-holding capacity in the soil at the onset of precipitation.

For both methods, we estimate soil water-parameters using a series of pedo-transfer functions and assume that the soils have 30% of their plant-available water-holding capacity available at the onset of the storm.

More details on these methods can be found in Appendix 3.

Results:

Current evidence supports only minor or moderate flood mitigation ecosystem services from soil health improvements on agricultural land in Vermont. The Figures 9 & 10 summarize the average runoff reductions for the two simulated storms. Except for conversion of row crops to hay, impacts are generally between $^1/_6$ inch and ½ inch. Monetary valuations are unlikely to reach levels relevant to farmers, at least on average. Corresponding monetary valuations are at or below $6.00/acre/year (Figure 11).

[10] The Green-Ampt equation is a simulation model describing how rainfall infiltrates into a soil, based on several soil physical parameters, including available water capacity and saturated hydraulic conductivity. For a detailed explanation, see: http://www.alanasmith.com/theory-Calculating-Effective-Rainfall-The-Green-Ampt-Method.htm. The Green-Ampt method is over 100 years old, but still widely used; along with the curve number method, it is one of two options for simulating runoff in SWAT and EPIC/APEX. We implement a Green-Ampt model with 3 distinct soil layers.

For the best soil-health scenario, runoff reductions range from ¼ to ¾ an inch. Corresponding valuations are from $1.50 - $4.00 /acre

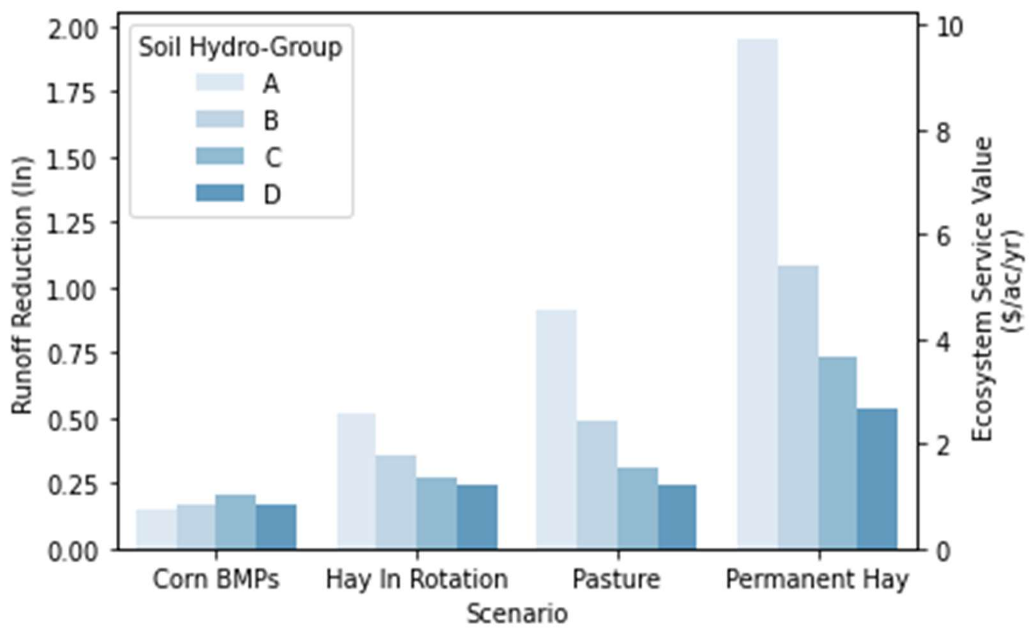

Figure 9: Runoff Reductions (4-inch storm) and Ecosystem Service Valuation for changes in Soil-Health Practices (Reference Case: Row Crops, Conventional Tillage) Left axis reports predicted changes runoff, and right axis reports the economic value of these changes.

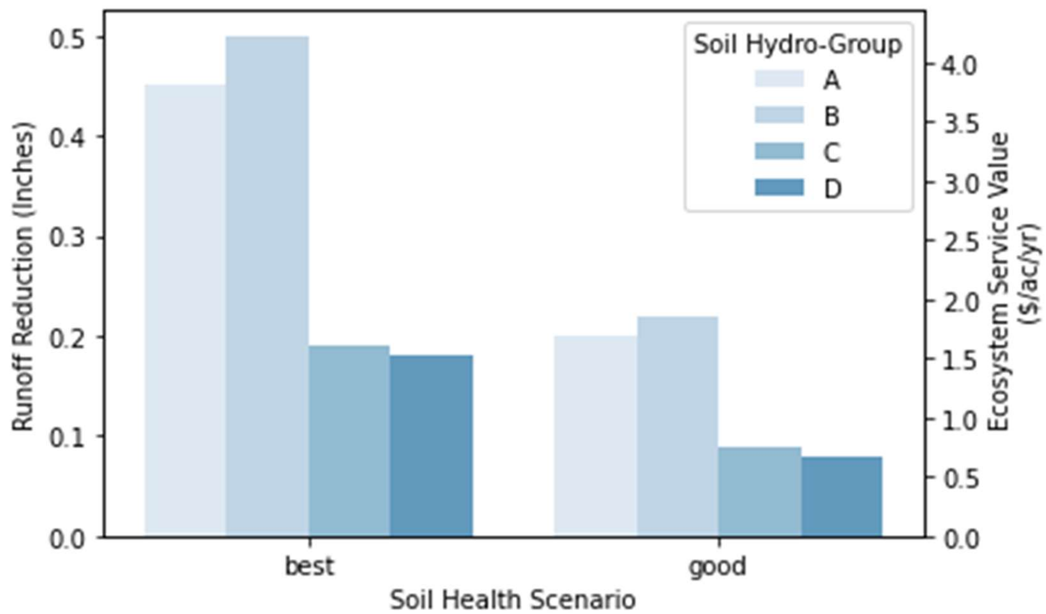

Figure 10: Runoff Reductions (4-inch storm) and valuation in Good and Best Soil-Health Improvement Scenarios. Left axis reports predicted changes runoff, and right axis reports the economic value of these changes.

Variation in Service Provisioning and Value:

There is some of variation in potential increases in runoff mitigation from farm fields; the same changes may mitigate twice as much runoff in some locations as in others. But the economic value of mitigating an inch of runoff is much more variable, spanning several orders of magnitude. As noted before, a large proportion of Vermont farmland is at low elevations, and communities with the largest historical river-flood damages are relatively high in their watersheds. To examine variability of potential flood-control services, we use the method described by Watson and colleagues (2019)[11] to quantify spatial variability in the "demand" for flood-control services. This method attempts to quantify the relative value of mitigating the same amount of runoff from different locations[12]. By normalizing the resulting scores for agricultural

[11] We assign a score to each pixel in Vermont based on the number of downstream structures at risk of flooding. It is calculated for each pixel as:

$$F = \sum_{a=1}^{n} {B_A}/{W_A}$$

Where a is each flood-prone area downstream of the pixel, B is the number of buildings in the flood-prone area and W is the area of the upstream watershed of that flood-prone area.

[12] Intuitively, a gallon of runoff to a creek which flows directly into Lake Champlain contributes far less to flood damages than a gallon of runoff from the town of Orange into the Jail Branch of the Winooski River, which will pass by thousands of structures and dozens of miles of road before reaching the Lake. This method attempts to quantify this difference.

land, we keep the *average* value of flood mitigation services on agricultural land but weight the ES value by this flood control demand score.

Our results show that the relative values of flood-protection services from farm fields follow a fat-tailed distribution[13]: the "typical" farm field has a much lower value than the "average" one. While runoff from some farm fields endangers no structures at all[14], some fields sit high in the watershed, protecting many large settlements. If payments were apportioned based on downstream flood risk, these fields could be eligible for much larger payments for their reduction in potential runoff during large storms. These farm fields are largely located in the upper reaches of the Winooski River watershed, one of the few places in the state where a high concentration of farms is upstream from substantial infrastructure and people (Figure 11). Table 4 presents the range of Ecosystem Service presents potential ecosystem services valuations for farm fields under the "best" soil health scenario. These values conserve the *average* Ecosystem Service valuation of flood runoff mitigation.

Table 4: Distribution of Ecosystem Service Valuations for Flood Reduction from Soils with "Best" Improvement Levels.

ES Value ($/acre)	*% of Agricultural Area in Range*
< $0.25	36.6%
$0.25 - $1	27.3%
$1 - $2	12.2%
$2 - $5	13.4%
$5 - $10	4.5%
>$10	5.8%

[13] Our results roughly follow the 80-20 rule: about 80% of the protection values come from 20% of farm fields.
[14] On the other hand, mitigating runoff from some these fields is likely to be very important for protecting water quality, as discussed in the section on phosphorus.

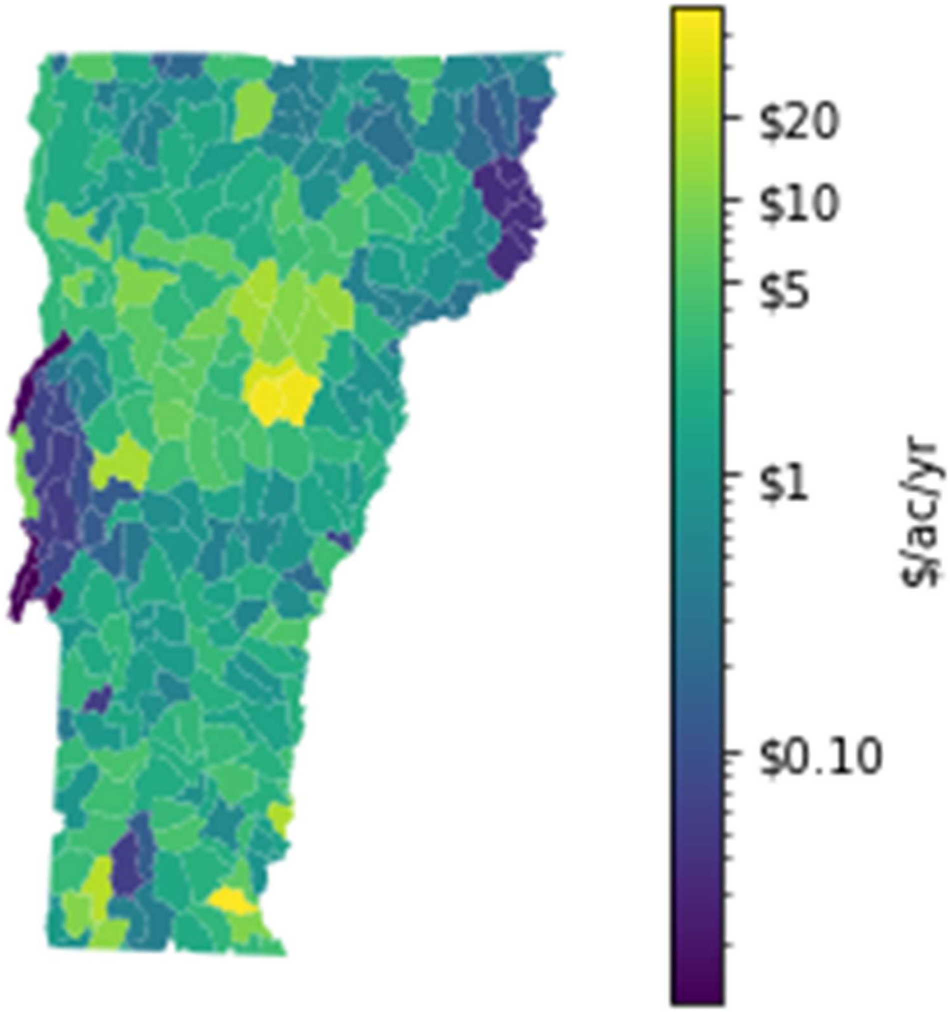

Figure 11: Ecosystem Service Value of Reducing Large-Storm Runoff from Agricultural Land by .3 inches (average for the "best" soil-health scenario.) Reducing runoff is much less valuable in areas near Lake Champlain, and much more valuable in the headwaters of the Winooski River.

Caveats and Areas for Future Work:

There are several weaknesses in our analysis, some of which may bias our estimates towards underestimating actual benefits, others which may bias them towards overestimating values. These are summarized in Table 5. Most important is the assumption of linear damages- some runoff-generating events do no damage at all, while many floods are subject to threshold effects, where a small increase in flow may cause dramatically greater damages. In addition, several types of damages may not be well-accounted for, including damages to natural capital and the economic and social costs of disruption while damaged infrastructure is un-usable.

A few factors may cause our estimates to be too high. First, some flood events occur when the soil is already complete saturated. This gives little opportunity for increased water-infiltration or holding capacity to mitigate runoff. Some of our methodological simplifications may also tilt the estimate upwards. For instance, our estimates of agricultural land-use in damaged towns' contributing watersheds are sometimes much higher than they should be to reflect the areas contributing the most to flood risk.

Edge-of-Field and Whole-Farm Interventions:

Several interventions that are not focused on soil health and are therefore outside the scope of this report are very important for flood mitigation. Overall land-use in agricultural basins is known to strongly influence stream channel flooding dynamics. Agricultural areas on well-connected floodplains provide critical opportunities to slow the movement of water and reduce storm peaks. These services may reduce downstream flood risk substantially. Other practices such as riparian buffers, constructed wetlands, artificial ponds and swales could increase infiltration, slowing and storage of floodwaters as well, and a PES program might pay for these services. Additionally, where agricultural lands are threatened by development pressures, agricultural land-cover provides substantial flood-control ecosystem services relative to developed land with substantial impervious surfaces.

Table 4: Major Sources of Uncertainty in Our Estimates of Flood Control Ecosystem Services

Factors That May Lead to Under-estimates	**Explanations/Examples**
Assumption of Linear Damages	Reducing floodwaters by 90% in many cases could eliminate 100% of damages. Given the small role of agriculture in the most disastrous floods, this is minor for "Generational Floods," but may be a larger issue for more minor flooding.
Social Costs of Infrastructure Disruptions	The costs of re-building a roadway are easy to quantify. The costs of that roadway being less usable while being rebuilt are less-so. Similar for power outages, etc. Irene was noted to cause disruptions to the crucial foliage tourism season.
Repair Costs of very minor floods.	Damages from frequent smaller floods cause damages to public infrastructure (e.g. dirt roads) that may be difficult to quantify.
Damages to Natural Capital	Flooding and fluvial erosion contribute substantially to many hard-to monetize damages from pollution. These include damages from erosion and nutrient deposition, as well as hazardous waste contamination.
Factors that May Lead to Over-estimates	
Many of the most damaging storms occur when soils are saturated.	Greater infiltration capacity gives little runoff-mitigation benefit when the soil is already saturated. Our estimates for increases in infiltration are based on soil available water capacity being 70% filled.
Town watersheds incorporate all areas upstream, sometimes overestimating the importance of agricultural landcover.	Often, small waterways with very low agricultural landcover cause a large proportion of damages. For instance, the Cold River (<2% ag landcover), accounted for a large proportion of Irene damages to Clarendon and Rutland. The total upstream agricultural landcover for both towns, which is what is used in the analysis, is >7.5%[15].
Simulating Runoff only for Large Storms	For smaller storms, the % of runoff averted by soil health is greater, but the absolute quantity will be smaller. For soil-health practices, the curve-number method is known to underestimate runoff in severe storms, leading to higher estimates of mitigation values.

[15] Similarly, most damage in the town of Hartford (~8.9% agriculture in its watershed) occurred in the Village of Quechee on the Ottauquechee River, which has less than half the upstream agricultural landcover (~3.7%). In a non-Irene example, severe flooding in Bellows Falls (Rockingham VT, 6.5% Agriculture in its watershed) in 2021 was due to the Hyde Hill Brook, which appears to have no agriculture in its watershed.

EROSION

While soil erosion is often thought of a direct threat to agricultural sustainability and productivity[16], it is also associated with many off-site environmental harms. One of the largest of these harms is the contribution of nutrients in eroded soil to freshwater eutrophication, which is covered in the Phosphorus section of this report. These costs include stream and reservoir sedimentation, which can reduce recreational value, harm wildlife and fish, increase flood risks and reduce the working life of dams.

Valuing Soil Erosion:

For soil-erosion impacts, we use a simple "value-transfer" method- we use other researchers' estimates of damage costs. Hansen and Ribaudo (2008) estimated off-site harms from erosion for every county in the United States. We exclude freshwater water-quality impacts, which should mostly be reflected in the next section on phosphorus. The number includes increases in water-treatment costs and damages to flood-control structures, farm ditches and marine fisheries. Their estimates for the 14 counties of Vermont range from $7.26 - $7.69 /ton of eroded sediment for an average of $7.38/ton in year 2000 dollars or $11.20/ton in 2020 dollars.

Hansen and Ribaudo's estimates are more geographically precise, but their estimate of average social costs of erosion for the whole United States are similar to several other estimates. Their estimate is $5.63 (USD2020) / ton while at least 3 other researchers found values between $5 and $6 per ton (Campbell, 2018; Pimentel et al., 1995; Uri, 2001). Social costs of erosion are substantially higher on a per-ton basis in Vermont and the rest of the northeast than in most other parts of the United States.

Estimating Physical Quantities:

The Universal Soil Loss Equation (USLE) is a family of simple models used to estimate soil erosion losses from farm fields. One of the parameters of USLE relates directly to soil properties, the soil erodibility or "K" factor. Wischmeier and colleagues developed an equation linking soil texture, organic matter and saturated hydraulic conductivity to the K factor (Wischmeier et al., 1971)[17]. We use this equation to estimate the impacts of soil health changes on soil erosion, using a family of reference scenarios for the other USLE parameters. Likewise, for soil-health practices,

[16] For on-farm values of erosion control, we can consider the cost of replacing organic matter lost in eroded soil. There are roughly 400 lbs of organic matter in a cubic yard of compost. If the eroded topsoil contains about 4% organic matter, then replacing organic matter requires roughly 1 ton of compost for each 5 tons of topsoil lost.

[17] The Wischmeier equation is the default option for calculating the K factor in SWAT. Another popular option is the equation developed for EPIC/APEX by Williams (1995). The Wischmeier equation is chosen because it incorporates two soil-health parameters (Organic Matter and Saturated Hydraulic Conductivity), while the Williams equation incorporates only Organic Matter. The Wischmeier method also covers greater range of soil organic matter concentrations than the Williams method.

we alter the "C" or crop-cover factor of USLE to develop estimates of changes in erosion losses with practice changes.

Further details on these methods, including limitations, can be found in Appendix 4.

Results:

Figure 12 summarizes the reduction in soil erosion from changing practices from the reference case of conventional corn. The "hay" scenario covers all perennial forages, including rotational hay, permanent hay and permanent pasture. Figure 13 summarizes reductions in erosion from improved soil health.

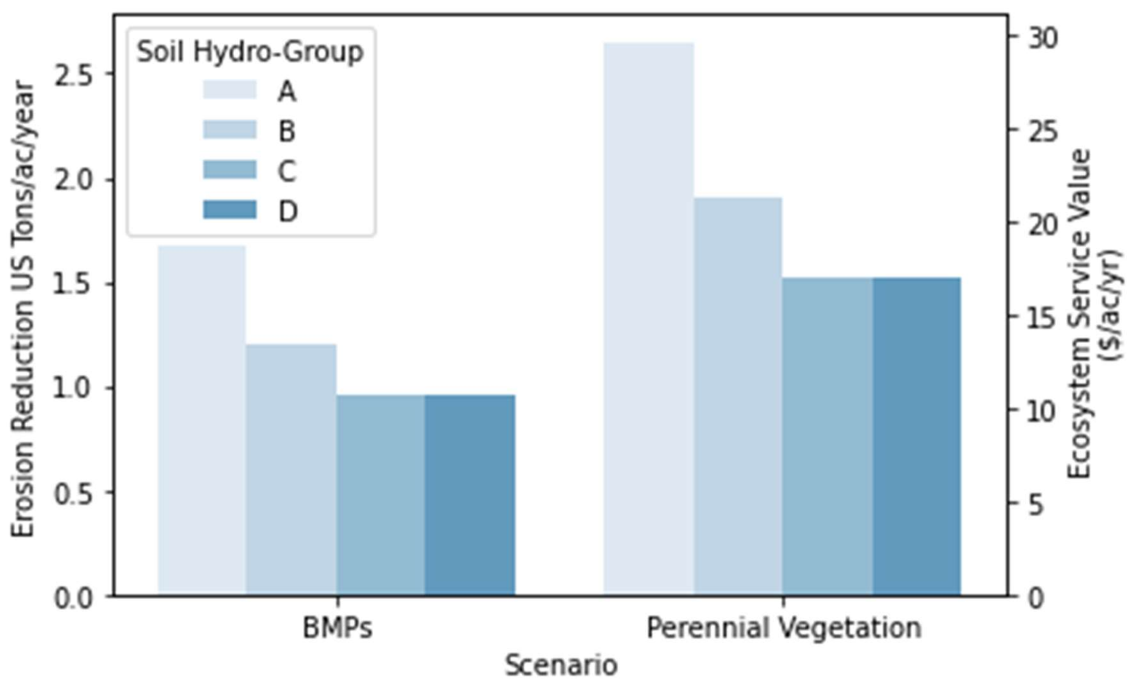

Figure 12: Predicted reductions in Erosion for Soil Health Practices and Ecosystem Service Value. Left axis reports predicted changes in erosion, and right axis reports the economic value of these changes.

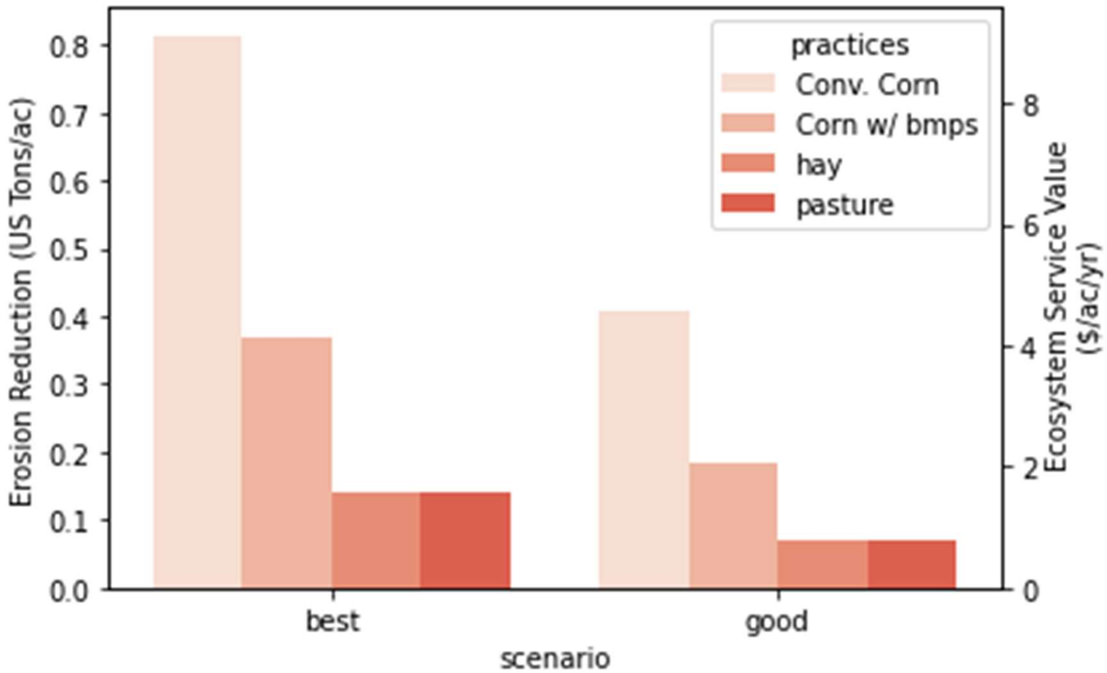

Figure 13: Predicted Reductions in Erosion for Soil-Health Indicator Scenarios and Ecosystem Service Value. Left axis reports predicted changes in erosion, and right axis reports the economic value of these changes.

Sources of Variation:

The value of erosion reduction services from healthy soil is higher on fields with steeper slopes, and higher on fields growing annual crops than those with perennial vegetation. We expect the same soil-health improvements to have similar percentage impacts on soil erosion, making the economic value much larger on fields that have high potential for erosion losses. The spatial variability in the value of damages done by a ton of eroded sediment is likely important, but not explored in this study.

Edge-of-Field and Whole-Farm Interventions:

Riparian buffer zones and other practices which can intercept eroded sediment before it enters waterways can greatly reduce the downstream damages of erosion. Likewise, substantial quantities of sediment can be generated by streambank erosion, which can be mitigated by bank stabilization practices, as well as any practices that reduce flooding as discussed elsewhere in this report. A PES program might consider paying for these services as well.

NUTRIENT RETENTION: PHOSPHORUS

Phosphorus enrichment is the largest source of freshwater eutrophication globally, and agriculture is the largest contributor. In Vermont Lake Champlain and Lake Memphremagog and several smaller waterbodies have impaired water quality due to phosphorus from agriculture. In Lake Champlain, numerous cyanobacteria blooms have degraded water quality, causing major economic, quality-of-life, and health impacts on the people living near the lake. Healthy soils and some soil-health related practices may be helpful for retaining phosphorus on farm fields and keeping it out of freshwater bodies.

Valuing Phosphorus Damages:

We estimate the damage from Phosphorus loading to Lake Champlain by roughly scaling up the work of Gourevitch et al (2021) on costs and benefits of P reductions in the Missisquoi Bay watershed. Their work combines an integrated assessment model (IAM) which links P loading to phosphorus and chlorophyll-a levels in the bay, and econometric and epidemiological models linking Chl-a levels to home sales, tourism expenditures and cases of Amyotrophic Lateral Sclerosis (ALS)[18]. While this paper does not report a "social cost of phosphorus," the annual benefits of meeting the TMDL are calculated at $2 million / year by 2050. This gives an average benefit of $10.35/lb of P mitigated. We scale this number up in two different ways and take the average of the two methods.

In the first method, we assume that economic damages from poor water-quality are linearly proportional to the economic activity in nearby areas, approximate by the number of people living within 20 km of a waterbody multiplied by the average income[19]. Further, we assume it is related to the percentage exceedance of the TMDL target. We estimate the marginal benefit curve of P reductions relative to exceedance of the TMDL using the 6 different scenarios examined by Gourevitch and colleagues and find a log-log relationship. We use data on the scale of required P mitigations under the TMDL (US EPA, 2016) and population data from the US Census. Using this, we estimate total benefits annual from meeting the TMDL, and divide these by required reductions.

This method yields an average damages of $30.42/lb of P from agriculture across Lake segments. Damages range from $6.35/lb for Otter Creek, $10.35/lb for Missisquoi Bay, to $678.83 / lb for Burlington Bay. Missisquoi Bay has large overshoot of its TMDL and the area around it is economically depressed and sparsely populated, while about 100,000 people live near Burlington Bay, including some the state's wealthiest communities.

[18] The causual linkage between ALS and cyanotoxins is still controversial.

[19] In Gourevitch et al, ALS cases are a relatively small proportion (10-15%) of monetized damages. Scaling these by income is obviously inappropriate, but damages to home prices and tourism, should scale to levels of economic activity moreso than population. On the other hand, lower-income communities may have a harder time adapting to poor water quality, and the public may have a higher willingness to pay to mitigate harms on them.

In the second method, we use estimates from Voigt et al (2015) for impacts on tourism revenues for the whole lake. Voigt et al (2015) used a series of regression models to estimate the impact of P load on water clarity (Secchi depth), and water clarity on property valuation, tourism expenditures, and regional economic activity. In their model, a 34% reduction in lake-wide mean total phosphorus concentration (corresponding to a 34% reduction in phosphorus load to meet the Vermont TMDL) would increase Secchi depth by 1.67 meters, and a 1-meter increase in Secchi depth across the lake is worth $12.6 million/year in tourism expenditures. Given the phosphorus TMDL for Lake Champlain Vermont reduction target of 234.7 US tons of phosphorus per year, this implies an average benefit of ~$45 (USD 2020) / lb of P-load reduction in tourism expenditures alone. Increasing this to reflect that Gourevitch et al estimate tourism losses as 54% of total economic damages, this yields a social cost of phosphorus of $82.72 / lb.

The average of these two values: $87.72 and $30.42, is $56.60 /lb.

Additionally, we use data from Beaulieu et al (2019) to estimate the impact of meeting the TMDL on methane emissions in Lake Champlain. They estimate that reducing P levels by 25%[20] in all global lakes with similar size and TP levels to Lake Champlain would reduce global annual methane emissions by 129000 metric tons/year. Lake Champlain's proportion of this is 3714 metric tons of methane. At a carbon-offset adjusted price of the social cost of methane, this yields over $1.8 million in annual benefits, or $3.97 / lb of P loading reduced.

Adding in this value gives $60.56 / lb of P for the Champlain Basin. We value P in the Lake Memphremagog Basin, which is also severely impaired, at the average level for Lake Champlain. About 25% of VT farmland is outside the Lake Champlain and Memphremagog Basins. We assign these areas the value for the Missisquoi Bay basin, $14.37 /lb.

This yields an average valuation of $56.82/lb. This estimate is highly imprecise, and is not exhaustive of harms done by eutrophication of freshwater bodies in VT. Not included in this analysis are the "consumer surplus" from tourism/recreational activities, above the increased spending at local businesses, other health benefits from clean water, reduced costs for treatment of drinking water and reductions in risks of catastrophic changes in the ecology of Lake Champlain. We are not able to estimate how movement of Phosphorus between different Lake segments, rather than treating segments as distinct waterbodies, might impact the valuations given.

More details on this valuation can be found in Appendix 5.

[20] The TMDL requires that P loading be reduced by 33% across the entire lake.

Estimating Physical Quantities:

To estimate reductions in P losses, we use the VT P Index (Jokela, 1999), a spreadsheet-based model used by farmers for nutrient management planning. The VT P Index includes the soil-health practice scenarios we investigate here, so these are directly simulated. The results presented average over a family of reference scenarios for innate site characteristics (slope, distance to water, soil type).

We were able to incorporate changes in soil health indicators in two ways. First, the P Index requires an erosion rate, for this we utilize the impacts on erosion losses developed previously. Second, we simulate the impacts on runoff across a wide variety of storms using the same methods as described in the section on flooding, to estimate how soil health reduces growing-season runoff, and therefore P losses in that runoff. The results presented average over reference scenarios for management parameters; which are conventional corn and the other soil-health practice scenarios.

Further details for these methods can be found in Appendix 5.

Results:

Figure 14 shows the estimated reductions in P losses for practice changes, relative to conventional corn. The corn best-management practices are simulated to have large impacts on reducing phosphorus levels. These BMPs were designed for P mitigation, so this result is unsurprising. Converting to perennial vegetation, such as hay, is modelled to have smaller benefits, and benefits that decrease with soil drainage, likely due to manure being spread on the soil surface.

Figure 15 shows our results for the soil improvement scenarios. Soil health improvements can have substantial impacts on P losses, especially from conventional corn. Soil health improvements have a smaller benefit for perennial vegetation, where P losses are lower to begin with.

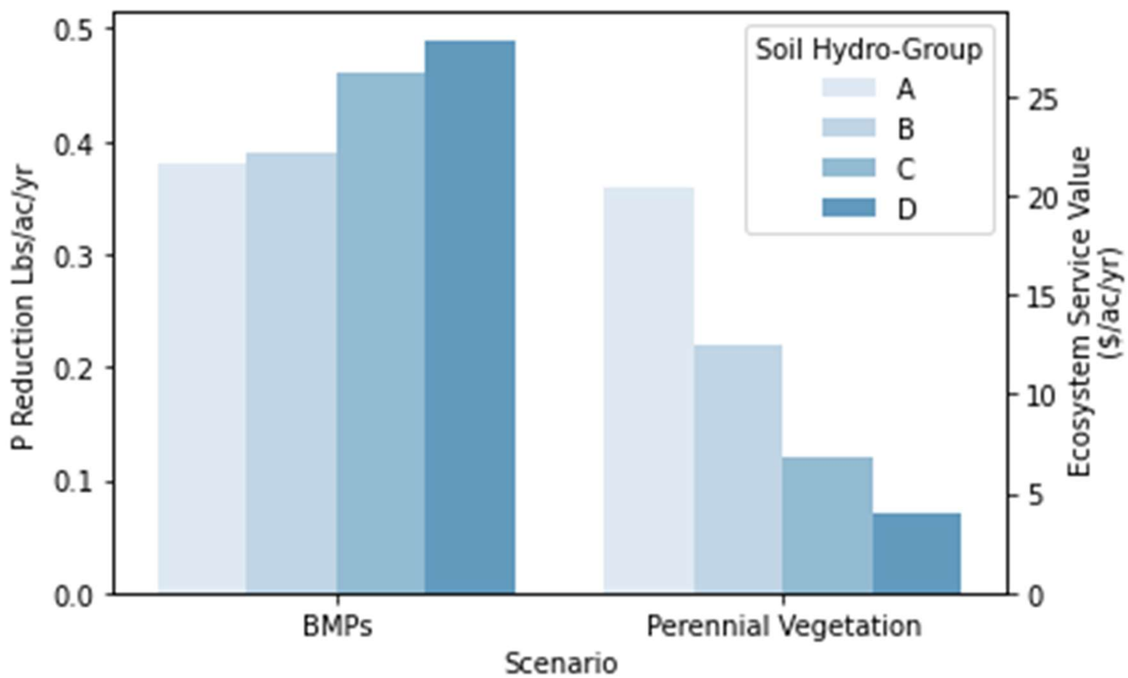

Figure 14: Reductions in P Losses for Soil Health Practices Scenarios and Ecosystem Service Value. Left axis reports predicted changes in phosphorus loading, and right axis reports the economic value of these changes.

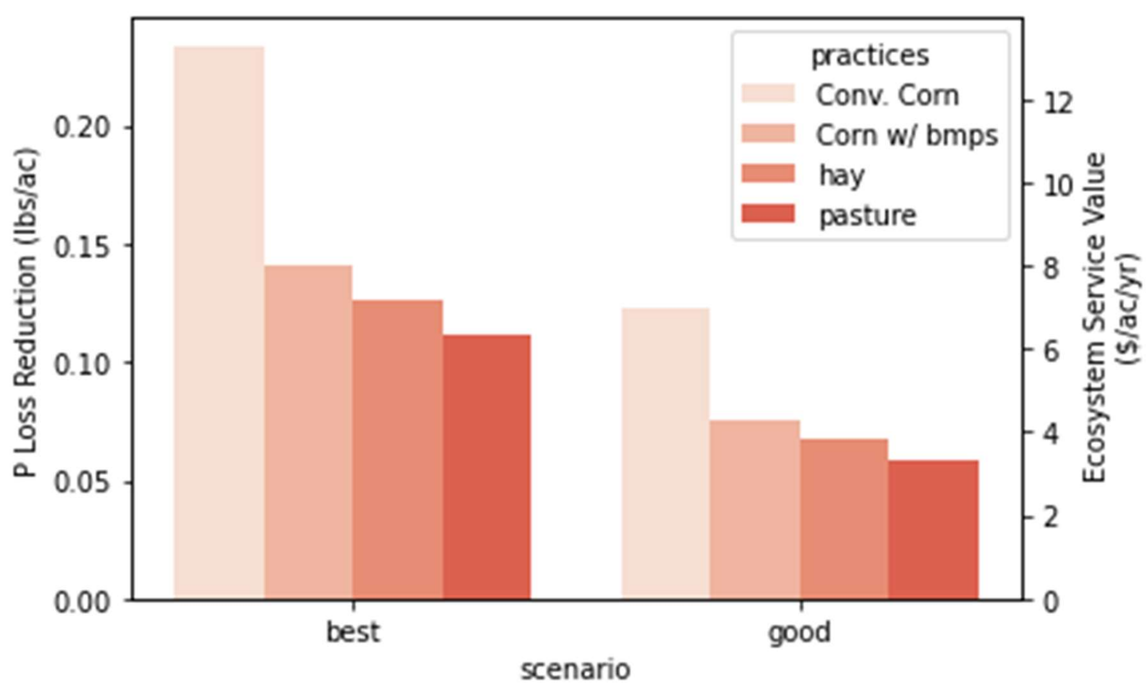

Figure 15: Reductions in P Losses for Soil Health Indicators Scenarios and Ecosystem Service Value. Left axis reports predicted changes in phosphorus loading, and right axis reports the economic value of these changes.

Sources of Variation in Service Value:

Improved soil health can reduce erosion and can reduce runoff, which are two important pathways for Phosphorus losses from farm fields. All else equal, we should expect reductions erosion and runoff to be proportional to P losses from erosion and runoff. As noted above, these reductions in P loss may be largely or fully offset by increased subsurface losses of P, on fields with substantial connections to waterways via subsurface drainage. Similar to erosion-control, the quantity of P-retention services provided by healthy soils is proportional to the field's potential to lose Phosphorus. Healthy soils provide a greater benefit in P reduction on fields growing annual crops, on steeper slopes, closer to waterways. Therefore, a large increase in soil health has a smaller value if other P-conserving practices are already implemented.

Beyond this analysis, most important soil-health indicator for P loss is **soil test phosphorus**. High soil-test phosphorus levels make it extremely difficult to keep P losses from farm fields to acceptable levels.

The largest source of variation in the value of P retention services is location in a sub-watershed. P retention is much more valuable in some sub-watersheds of the Lake Champlain Basin than others, and is generally more valuable in the Lake Champlain basin than outside of it, though this may be variable based on smaller impaired waterbodies throughout the state[21]. The variation in values is driven by the potential of downstream waterbodies to become eutrophic from Phosphorus loading, and the scale of human uses of those waterbodies. It may be even more valuable in specific sub-watersheds flowing into highly impaired lakes and ponds.

Caveats and Areas for Future Work:

Soil health metrics, and soil health practices can be effectively linked to expected reductions in erosion and runoff, nutrient losses through these pathways are proportional to these quantities, holding all else equal. Greater water infiltration may, however, increase nutrient losses downward through the soil profile, which may be especially harmful in soils with pattern tile drainage, or other direct connections to waterways via subsurface flow (Duncan et al., 2019).

Our results treat all phosphorus equally, and this assumption is untrue. Generally, soil health improvements and practices are more effective a reducing sediment-bound Phosphorus, than dissolved Phosphorus. Given that sediment-bound phosphorus is less bio-available to algae than dissolved Phosphorus, the monetary valuation for sediment bound phosphorus should be lower, and that for dissolve phosphorus should be higher.

[21]Other than Lake Champlain, there are 8 waterbodies that are either declared impaired by P and/or have had a TMDL drawn up for P since 2001. Two of these waterbodies: Ticklenacked Pond in Ryegate, and the Black River, are outside of the Champlain or Memphremagog Basins.

Our valuation of phosphorus loading is substantially lower than the State's demonstrated willingness-to-pay for phosphorus reductions from agriculture. Currently, the Pay-for-Phosphorus program pays farmers $100/lb of phosphorus load reduction and pays even more for reductions in loading from other sources. The State of Vermont is legally required to meet the TMDL, even if doing so creates more monetary costs than benefits. Using costs or payment rates for other ways of reducing phosphorus loading would result in a higher, and possibly more realistic number.

These results should be interpreted with caution. The estimates for soil-health practices are made purely using the Vermont P Index, a tool that, despite uncertainties, is widely used for communicating with and regulating farmers around water quality issues.

Edge-of-Field and Whole-Farm Interventions:

As with other services, there are several practices that contribute greatly to reducing P loads and could be incorporated into a broader PES program.

OTHER ECOSYSTEM SERVICES

Nitrogen:

There are several types of N losses from agriculture which harm ecosystems and human health through a variety of pathways. Gaseous losses, including ammonia, nitric oxides and nitrogen dioxide contribute to acidification of water and soil, and can damage air quality both directly and through their impacts on particulate formation. Water-borne losses of nitrate, including leaching and runoff, can damage drinking water resources and contribute to eutrophication of marine ecosystems. Nitrogen lost from the soil can also change form after leaving the soil - nitrate in runoff will eventually be denitrified and turn into N_2O, NO or NO_2, while some gaseous emissions will be deposited in soils that they may subsequently leach from.

Valuing N Losses:

The spatial complexity of N emissions and their harms calls for a full study of its own, but Table 6 summarizes best-estimates of the average economic harms done by different pathways of reactive nitrogen emissions in the United States. Note that some of these, such as respiratory disease, may have much smaller impacts in VT, which has low population density and few population centers downwind.

Table 5: Average US Values for Damage costs from Different types of Nitrogen Emissions, based on Sobota et al (2015).

N Loss Pathway	*Damage Valuation per Lb of N*	*Largest component*	*Notes*
NO_x	$15.88	Respiratory Disease (79%)	Beneficial for climate
NH_3	$6.07	Ecosystem Change (69%)	Beneficial for climate
N_2O	$6.87	Climate Change (79%)	Climate number from (Marten & Newbold, 2012), adjusted down for offset price.
Surface freshwater	$10.33	Eutrophication (85%)	
Groundwater	$1.33	Colon Cancer (72%)	
Costal Water	$12.12	Fisheries (71%)	

In estimating damages from nitrogen leaching, we take the weighted average of groundwater, costal water and surface freshwater, weighting groundwater at 80%, and the others at 10%. This yields $3.31/lb of nitrogen.

Impacts of Soil Health on Nitrogen Losses:

To estimate impacts of soil health changes on losses of nitrogen, we parameterize the DayCent model (Parton et al., 1998) on the "current-practices" management activities for Hay and Corn used in recent agri-environmental field trials in Vermont (White et al., 2021) and the simulated soils that we generated. We use weather data from Burlington International Airport for the years 2012 - 2021 Simulated impacts of soil health on gaseous nitrogen (and methane) losses are relatively small, and highly variable. Figure 16 presents a summary of impacts of different scenarios on nitrogen and methane flows, presented in dollar terms.

In the large majority of crop-soil pairs, greater soil health resulted in larger losses of NO-N and methane, and somewhat smaller losses of N2O-N. Median values were at or below .2 lbs/acre/year, and on net correspond to roughly $3-4/acre/year in *damages* from increased soil health.

Impacts on nitrogen leaching were the largest, and also the most variable. The 'best' soil health scenario generally results in higher losses of nitrogen through leaching, this was the case for 71% of the soil-year pairs for corn, and 92% for hay. Median increases in nitrogen loss through leaching were 1.47 lbs/acre/year for corn, and 3.53 lbs/acre/year for hay, differences valued at $5 - $12/acre/year in *damages* from improved soil health.

Much of these additional N losses through leaching may be due to additional nitrogen being mineralized from soil organic matter. If farmers account for additional N from OM mineralization in their nutrient management planning, this impact may disappear. If the farmers in the 'best' soil-health scenario respond by reducing manure applications by 10%, then NOx losses are unchanged from the baseline scenario, while modelled nitrate leaching losses decrease from baseline, yielding small net benefits, rather than damages.

Daycent lacks the capacity to model surface runoff losses of dissolved nitrogen. In recent experiments, surface runoff of dissolved nitrogen from Vermont crop fields was on the order of 1 lb per acre (White et al., 2021). Given the valuations presented in Table 6, this places an upper bound of a few dollars per acre on the value of soil-health improvements for reducing nitrogen losses through this pathway.

Impacts of Practices on Nitrogen Losses:

Cover-crops show substantial reductions in loses of nitrogen through leaching; a median of nearly 5 lbs per acre, valued as a monetary benefit of over $30/acre. Impacts of cover crops on N loss through other pathways were beneficial, but very small. Manure injection, another aspect of the corn BMPs scenario may result in substantial increases in N losses, especially from leaching and from nitrous oxide (Barbieri, 2021). As currently configured, DayCent is unable to simulate manure injection.

Given these relatively small and variable values and the high uncertainty, we do not include Nitrogen and trace gases in our valuation. It is possible that this method over-estimates nitrogen losses from higher soil-health scenarios, as actual farmers often account for the increased N mineralization from organic matter in their nutrient planning and apply less N to their fields in manure and fertilizer.

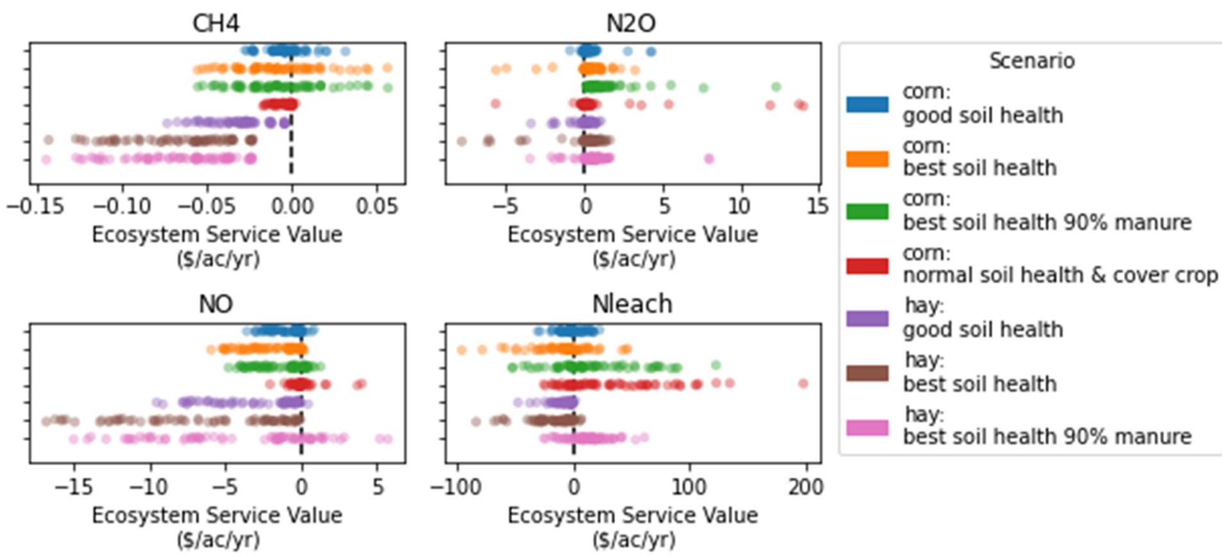

Figure 16: Value of Net Ecosystem Service Benefits from Changes Trace Gases and Nitrogen Leaching (Base Cases: Corn, normal Soil Health; Hay, normal soil health). Negative values indicate environmental damages from soil-health improvements, each dot represents a simulation of one soil series for one year. For all losses other than leaching, impacts are small, and highly variable.

Soil Biodiversity:

Several options exist for valuing soil biodiversity, though none of these are feasible within the scope of this study. There are 3 general types of values contributed by soil biodiversity. First, soil biodiversity is linked to supporting ecosystem services including nutrient cycling, predation, and soil aggregation, which may enhance other ecosystem services, including crop production and the services discussed in this paper. Second, soil biodiversity may have insurance value: soil biodiversity may enhance the resilience and stability of important soil ecosystem services. Lastly, soil biodiversity may have existence value, the people in Vermont may derive economic value from knowing that their soils are biodiverse, regardless of any direct impacts on human-wellbeing.

The first two types of value are important questions, but too little research exists to conduct a meaningful valuation of changes in soil biodiversity; no available models can link a unit-change in soil biodiversity with a unit-change in soil resilience. For existence value, stated-preference methods, such as contingent valuation surveys could be used to understand Vermonter's willingness-to-pay to improve soil biodiversity, but these methods may be unreliable for something so abstract. It would be hard, for instance, to ensure that respondents do not include any impacts on the other services examined in this report in their willingness to pay; if they did, this would result in double-counting.

Conclusion and Next Steps

In this report, we estimate the levels and values of 4 ecosystem services promoted by healthy soils and by soil-health practices. We show that the public values of these services are of reasonable size and may justify a program for payments for Ecosystem Services. While these estimates are necessarily rough, they also can provide general guidance to understanding the sources of variability in these values and their relative magnitudes.

Several areas require further work to better understand. First, better estimates of Nitrogen may be quite valuable - the relative magnitudes of benefits from reducing N losses look to be substantial. Second, estimates of the benefits from edge-of-field practices and other non-soil-health practices may also be useful. For example, it is likely that re-establishing riparian forest would have similar or greater per-acre benefits for all four of these ecosystem services than any soil-health practice or improvement[22]. Third, further research could refine the estimates of the dollar values of other Ecosystem Services. For all of the services included, the estimates that we provide for their dollar values are preliminary and would benefit from refinement.

Two areas could use deeper examination in particular. First, our valuation of phosphorus is both crude and leaves out several important harms of impaired water-quality. Better understanding these economic harms could help identify clean water beneficiaries and identify revenue sources and win-win solutions. Second, more work should be done to understand the impacts of upstream landscapes on flood resilience further downstream. Beyond the role played by agriculture and soil-health, identifying the highest-value locations and practices for flood mitigation will become increasingly important as Vermont becomes warmer and wetter.

The science on the ecosystem services from healthy soil is still in its infancy. The science linking sustainable and regenerative agriculture practices to soil health increases and ecosystems services is also new and sparse. While new research will continue to refine our understanding, the estimates provided here can guide the creation of policy with the information we have today.

[22] For instance, two recent studies (Gourevitch et al., 2020, 2022) find very large impacts from floodplain forest restoration on flood risks downstream, aboveground forest carbon storage in the Northeast exceeds 30/T acre (Heath et al., 2002) and buffer zones along agricultural fields are highly effective at reducing sediment and nutrient loading (Yuan et al., 2009).

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Technical Appendices: Valuation of Ecosystem Services from Soil Health.

Contents

Appendix 1: Scenario Development:

Practices:

The practices scenarios are derived from the list used to inform the Vermont Payment for Ecosystem Services Technical Research Report #2. These include 1) no till and cover cropped corn, 2) corn in rotation with hay, 3) transition to perennial pasture, 4) cover cropping in vegetable production, and 5) hay.

Indicators:

The % increases for soil health scenarios were partly chosen from a desire for clean, round numbers, and as such, are somewhat arbitrary. The "good" scenario represents levels of soil health differences that are often seen in long-term field experiments comparing conventional and best-management practices. In a review of long-term experiments, Crystal-Ornelas et al (2021) found that using best-management practices on organic farms increases SOC levels by an average of 14-24% compared to organic farming without these practices.

For the best scenario, we wanted to display a high bar that ambitious regenerative farmers believe that they can meet. According to data from the UVM soil testing laboratory, about 20% of commercial farm samples have SOC levels at least 50% higher than the median level for the state. This level of increase in soil organic carbon is also aligned with ambitious targets and claims by researchers and farmers in the regenerative agriculture community. For instance, the an analysis by Drawdown (Toensmeier et al., 2020) estimates that regenerative agriculture strategies on annual cropland in humid-temperate climates could sequester 7-13 tons C/acre[1] before soil carbon stops accumulating, and that managed grazing could sequester even more.

For Bulk Density, the regression model developed by Ruehlmann & Körschens (2009) predicts that the increases in soil organic carbon simulated for the scenarios would result in a 5% and a 10% reduction in bulk density respectively, due to the favorable impacts of organic matter on soil structure. This level is doubled to account for favorable impacts on soil structure from other changes.

[1]These numbers are reported as .6 Mt / ha /year for 25 to 50 years. Our "best" scenario is approximately 13 tons C / acre.

Appendix 2: Soil Carbon

Biophysical Quantities.

For soil-health indicators, the changes in carbon are assumed.

For soil health scenarios, the following data sources were used:

Scenario	Data Source	Notes	Link
Corn BMPS	Integrating Cover Crops and Manure into Corn Silage Cropping Systems		Link
Corn-Hay	Corn Cropping Systems to Improve Economic and Environmental Health		Link
Hay	Corn Cropping Systems to Improve Economic and Environmental Health		Link
Pasture	Corn Cropping Systems to Improve Economic and Environmental Health	Used Value for converting to Hay	Link
Vegetable BMPs	Evaluation of commercial soil health tests using a medium-term cover crop experiment in a humid, temperate climate (Chahal & Van Eerd, 2018)	Average of cover-crop scenarios.	Link

Table S 1: Data sources for Soil Carbon Accumulation in Practices Scenarios

Valuation:

For soil indicators, we value the climate regulation services of storing 1 ton of carbon in soil for 1 year. This approach makes the valuation comparable to the valuations of other ecosystem services, which are valued as yearly flows of benefits. The Social Cost of Carbon methodology gives a present *all* future costs and benefits of carbon stock changes It also avoids the possibility of large negative payments to farmers who are doing a reasonable job stewarding soil health.

We use two methods to estimate annual benefits of carbon storage.

In the first method, we use the "social cost of radiative forcing" as described by Rautiainen and Lintunen (2017), which describes the social cost of an additional unit of global warming in a given year. In their appendix A, Rautiainen and Lintunen estimate the social cost of radiative forcing as $358/nW/m^2. A ton of CO_2 increases radiative forcing by an average of .001476 nW/m^2 during the first 5 years after emission (Levasseur et al., 2010), which is a plausible re-sampling interval for a soil-carbon program. This gives $0.53/Metric Ton CO_2/year. Converting to imperial tons of carbon yields $1.76/ton/year, which we adjust downwards by 25% to account for the difference between the Social Cost of Carbon calculated by that study ($20/ton) and the $15/ton offset price used in this study. This yields $1.32/Ton SOC/year.

In the 2nd method, we use the social cost of carbon calculated by the EPA, and calculate the annual payment (in perpetuity) that has an equivalent net-present value at discount rate used. A lump-sum payment of the social cost of carbon of $51 is worth the same, at a 3% discount rate, as an infinite series of payments of $1.58/year. We adjust this downwards by the ratio of the social cost of carbon to the reference offset price ($15) and upwards to convert from metric tons CO2 to imperial tons carbon, yielding $1.55/T SOC.

Additional Issues:

Difficulties in Using the "raw" social cost of carbon:

A .1% change in soil organic carbon content corresponds with about .75 tons of carbon per acre. At the $53/ton of SOC offset price, this is valued at $40/acre, at the current US Social Cost of Carbon, it is valued at nearly $140/acre.

Even on relatively small crop-fields, soil samples properly taken from multiple cores will have some variability. Data from the Cornell soil lab shows that the standard deviation of soil organic matter for a small field with homogenous management can range from .13 to .39 percentage points (R. Schindelbeck, personal communication, April 15, 2022). A standard deviation of .2 percentage points in organic matter corresponds to a 0.164 standard deviation in *differences in organic carbon* between two samples from identical fields. This would mean that 27% of the time, a 2^{nd} successive sample of the same field, on the same day, would show at least a .1% decrease in SOC, and 10% of the time would show a decrease of at least .2% SOC.

If an annualized payment/valuation strategy is used, a decrease in soil carbon content of .2% would mean a reduction in payments of about $2.88/acre/year. If a lump-sum style offset/social cost of carbon valuation were used, it would result in a *negative valuation* of roughly $75/acre, spread across the number of years until the next sample.

Bulk Density and Measurement Error:

Despite the one-to-one linkage between Soil Organic Matter as a soil health indicator, and carbon storage as an ecosystem service, there are important complications in measuring soil carbon storage. These relate to the depth of measurement, and its relationship to soil bulk density. Soil organic carbon is usually measured to a reference depth, often 30 cm. If management of a soil results in substantial soil compaction, then more soil material ends up within 30 cm of the surface, increasing measured soil carbon storage, without increasing actual carbon storage (Figure S1). Lee and colleagues (2009) demonstrate these complications and recommend that changes in bulk density not be used to assess changes in carbon storage.

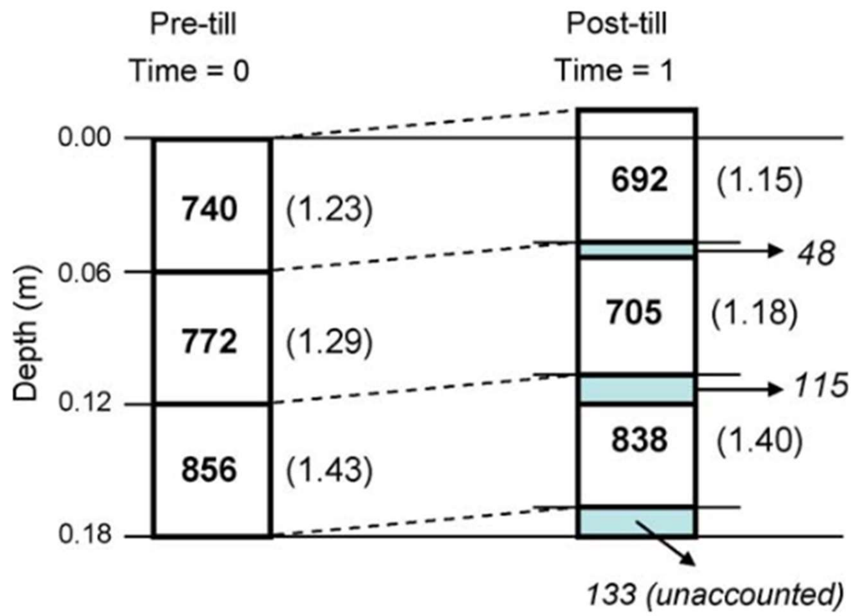

Figure S 1: Tillage decreases bulk density, expanding the volume that the soil layer takes up. Because of this expansion, some carbon is now below the depth of measurement. Figure from Lee et al (2009).

Appendix 3 Flood Mitigation:

Biophysical Quantities:

Practices:

Runoff for a 4-inch storm and a 1.5-inch storm is calculated for each land-use and the four soil drainage classes, using the NRCS curve number method. The curve number method is widely used, including as a component of basin-scale models such as SWAT and APEX. The NRCS curve number is a simple empirical model of rainfall infiltration curves.

Each combination of land-use, soil hydrologic class and practices was assigned a "Curve Number" from 30 to 100, based on decades of empirical research. The curve number is converted into a retention parameter, S through the following equation:

$$S = 25.4 \cdot \frac{1000}{CN} - 10$$

The rainfall-runoff curve is then calculated as:

$$Q = \begin{cases} \dfrac{(R - I_A)^2}{R - I_A + S} & if\ R > I_A \\ 0 & otherwise \end{cases}$$

Where I_A is normally set to $S \cdot .2$ and R is the rainfall for the day.

Indicators:

Runoff reductions for soil-health indicators are calculated as the average of two methods; the Green-Ampt equation, and additional water-holding capacity until saturation. For both, we assume that the soils start at 70% of their plant-available water-holding capacity.

For both methods, some additional parameters must be estimated first.

These include the saturated hydraulic conductivity and soil moisture contents at the permanent wilting point (ϕ_{pwp},) field capacity (ϕ_{fc},) and saturation (ϕ_s).

For these parameters, we utilize two different tools. First, we utilize the ROSETTA pedo-transfer function model from the USDA ARS (Zhang & Schaap, 2017), which calculates residual water content (ϕ_r), ϕ_s and Ksat, based on soil particle distribution (percents sand, silt, clay and organic matter) and bulk density and (optionally) ϕ_{fc} and ϕ_{pwp} . We also use the equations by Balland (2008) for calculating ϕ_{fc}:

$$\phi_{fc} = (.565 + .426 \cdot clay^{.5}) \cdot exp(-1 \cdot (.103 \cdot sand - .785 \cdot \frac{OM}{\phi_s/d_b}))$$

And ϕ_{pwp}:

$$\phi_{pwp} = \phi_{fc} \cdot (.17 + (.662 \cdot clay^{.5}) \cdot exp(\frac{1.4 \cdot OM}{\phi_{fc} \cdot -1})$$

For both equations, soil composition factors are fractions, not percentages, (0-1 rather than 0-100) and water contents are calculated on a weight, rather than volumetric basis.

Our estimates for the soil water parameters are made by first calculating ϕ_s using the Rosetta model and soil particle distribution and bulk density. The result for ϕ_s is used for the Balland field-capacity equation, whose result is used for the Balland permanent wiling point equation. The process is then repeated several times, with the values for ϕ_{fc} and ϕ_{pwp} generated by the Balland equations used to parameterize the Rosetta model. After five cycles, the final values are used.

Soil pore space is derived in 2 steps:

Particle density is calculated as (Schjønning et al., 2017):

$$d_p = 2.652 + .216 \cdot clay - 2.237 \cdot OM$$

Where OM and clay are reported as fractions.

And porosity is calculated as:

$$p = 1 - \frac{d_b}{d_p}$$

Where d_b is bulk density. This simply means that all space not taken up by particles is pore space and pore space has 0 dry-weight.

An additional parameter needed for the green-ampt equation is soil matric potential, the strength with which a soil holds the water. This is calculated using the equation developed by (Rawls & Brakensiek (1985) as described in the technical documentation of SWAT, page 109.

These results are used to parameterize the Green-Ampt Equation. We use a version with 3 unique soil layers. A general description of the Green-Ampt method can be found here. We simulate runoff for a 4-inch storm over the course of 6 hours for the “generational storm” and a 1.5 inch storm over 3 hours for 10-25 year return intervals.

Valuation:

Our estimate of the relative impacts of smaller floods vs "generational storms" in Vermont's flood risks are intermediate between the story told by available data on past damages and simulation modelling conducted by Gourevitch and colleagues (2022). The available data shows a "fat-tailed" distribution of flooding events: a majority of flood damages are attributed to a small number of extreme storms. Gourevitch and colleagues show the opposite: over 2/3 of modelled damages come from floods with a modelled return period of 10 years or less, and about half of modelled damages are from floods with a return period of 2 years.

The historical data show that rare, extreme flooding events account for the majority of flooding damages to buildings and property (Figure S*). Tropical Storm Irene accounts for 70% of all National Flood Insurance Program payouts for non-winter flooding in VT since 1976[2] (Federal Emergency Management Agency., 2021a). Given that Irene caused severe damages outside of mapped flood zones and through landslides not covered by the NFIP, this proportion may be an underestimate of its contribution to historical flood-damages. Similarly, 71% of all flood-related payments from the USDA Crop Insurance Program since 1988 were made for damages caused by Irene (Risk Management Agency, 2021). 89% of all FEMA-assessed damage to VT homes since 2002 was associated with Irene (Federal Emergency Management Agency., 2021b). Between 65% and 91% of FEMA grants associated with flooding made to Vermont communities since 1998 were associated with Tropical Storm Irene (Federal Emergency Management Agency., 2021c)[3]. Additionally, most smaller flood events have been due to storms that featured extreme rains (>3 inches) on a more localized basis (VT Emergency Management, 2018).

[2] We would expect soil-health to have very little impact on winter flood damages from ice-dams and snowmelt, though other agricultural management practices might have an impact.
[3] This very wide range is due to the "Severe Storm" categorization – a significant proportion of damages from "severe storms" can be due to wind and ice, but much is due to flooding.

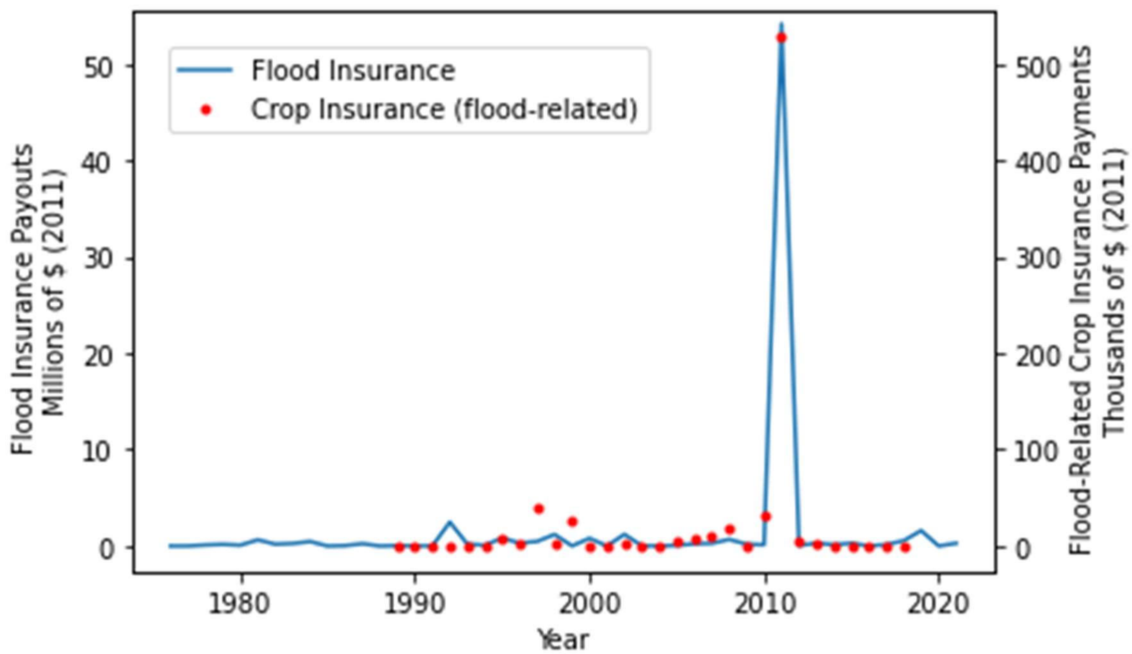

Figure S 2 Annual Payouts in Vermont for Federal Flood Insurance, and Crop Insurance Payouts for Flood-Related Damages. (Note that Crop Insurance payments are plotted at exactly 1/100th scale compared to Flood Insurance).

We reconcile the differences between these different methods by excluding modelled damages from the most frequent floods. We choose to exclude the estimated damages for these floods for several reasons.

First, it is hard to reconcile with existing data and other analyses. Other researchers consistently find the vast majority of flooding damages associated with low-recurrence floods. For instance, Wobus et al (2014) estimate that 98% of flood damages come from 25% of events.

Their estimates indicate that a year where all Vermont rivers flowing into Champlain experience a 2-year flood would yield $79 million in damages to buildings. In the last 11 years, the 75th percentile for total annual flood insurance claims for counties in the Champlain Basin is $375 *thousand*. Given that property owners whose properties are vulnerable to high-frequency flooding are substantially more likely to carry flood insurance[4], it seems extremely unlikely that flood insurance payouts would represent <.5% of *total damages to buildings* from frequent floods. For comparison, flood insurance claims accounted for about 4.8% of *total damages* from Irene, despite this storm impacting many areas that were not believed to be flood-vulnerable.

Second, a combination of intuition and the description of model uncertainty for probHAND given by the developers makes us cautious in interpreting their very large damage estimates for high recurrence floods. As Diehl and colleagues state:

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[4] Indeed, a common criticism of the NFIP is that many people only live in highly flood-prone areas because subsidized insurance is available to them.

> "Inaccuracies in mapped flood extents from low-complexity models may be particularly large in urban settings or at confluences where simple process representations do not capture local hydraulic conditions [20,24] and *greatest for floods with smaller peak magnitudes*, which are more heavily influenced by local topographic and hydraulic conditions than large floods… We found that probabilistic maps capture the distribution of uncertainty within a dataset of field observations of flood extents, and from calibrated hydraulic model output."

(Diehl et al., 2021, p. 14)

While this model may capture this uncertainty well in a technical sense, it is unlikely that it accurately captures the probabilities of property flooding in high-frequency events. The choices to build, repair or abandon structures are made by people who have at least some knowledge of local flood history; people are less likely to build homes in places that are known to experience regular flooding. The more frequent the flooding, the stronger this divergence is likely to be. For 2-year return flood events, model uncertainty is high, and the location of homes provides a strong signal about the ways in which the model is likely to be wrong.

Comparative References:

Antolinin et al (2020) used SWAT to estimate impacts of agricultural best-management practices on flood damages in agriculturally-dominated (~90% of land) sub-watersheds in Iowa. In their most aggressive scenario, where about half of cropland (over 40% of watershed area) moves to no-tillage and/or cover-cropping, reduces expected annual flood damages by 5.8%.

For our soil-health "best" scenario, applied across all farmland, yields about 2-3% reduction in overall flood damages; in Vermont, agriculture is roughly 14% of landcover.

With regards to the overall scale of flood damages, Wobus and colleagues (2014) estimate $44 million in annualized (non-costal) flood damages in New England, approximately .0045% of regional GDP, from flood events large enough to be included in the National Climate Data Center storms database[5]. Our estimates give the scale of annualized flood damages in Vermont as ~$98 million, about .38% of Gross State Product, two orders of magnitude higher. The Wobus estimate only includes the largest floods, and Vermont is likely much more vulnerable to river flooding than the highly populated areas of southern New England states.

[5] This corresponds to roughly the 208 largest flood events each year in the United States.

Appendix 4 Erosion:

Biophysical Quantities.

The Soil K Factor:

The Erodibility Factor (K) is one of the five[6] parameters of the universal soil loss equation (USLE), and it is the only factor that is directly influenced by soil-health indicators. The K factor describes the susceptibility of soil particles to detachment. Because the USLE is a multiplicative model, a 10% decline in the K factor corresponds to a 10% decline in erosion, for the same field with the same management.

We use the Wischmeier equation to estimate changes in the K factor. This equation takes the form:

$$k = \frac{.00021 \cdot ((silt + vfs) \cdot (0 - cla\ \ ))^{1.14} \cdot (12 - OM) + 3.25 \cdot str + 2.5\ \cdot (perm - \ \ )}{100}$$

Where OM, clay and silt are their percentage representation in the soil, vfs is percent very fine sand in the soil. Str represents a soil structure code (integer between 1 and 4) and perm is a soil permeability class code (1-6).

We modify this equation slightly by making the soil permeability code continuous, rather than discrete, calculating it as:

$$perm = 6 - log(Ksat)$$

with a minimum value of .9 and a maximum of 6.5 .

The other commonly used option is the Williams equation, developed for APEX/EPIC.

Its calculation several more steps than the Wischmeier equation, but only incorporates values for clay, silt, sand, and organic carbon as percentages of soil weight.

[6] Or 6, depending on whether the length and slope factors are calculated jointly or separately.

The scenarios for the USLE simulations are parameterized as described in table S2.

Parameter	Meaning	Value Used	Notes/Source
R	Rainfall Erosivity	97	EPA R factor calculator, average of points in NW Vermont.
K	Soil Erodibility	Calculated using Wischmeier Eq	
LS	Length-Slope	.6 for Corn, .75 for Hay/Pasture	Averages Calculated for Franklin County. For practice changes, .6 is used.
C	Cover Factor	Differs by Crop	Table from here
P	Erosion Control Practice	.9	Intermediate between cross-slope and up-and-down tillage

Table S 2: Parameters used for USLE for Calculating Erosion Losses

Caveats:

Our methods gives one major source of error, which may cause an underestimate of benefits. Sediment yield, the amount of eroded sediment which actually reaches waterways is heavily influenced by runoff volumes, and improvements in soil health reduce runoff. This is reflected in the Modified Universal Soil Loss Equation (MUSLE) which calculates sediment yield (rather than erosion) for each individual runoff event. It does this by calculating the USLE R-factor as:

$$R = (Q_{peak} \cdot Q_{surf} \cdot ha)^{0.56}$$

Where ha is area of the field in hectares, and Q_{peak} is maximum 15-minute runoff rate in m^3/s. Because of its exponential scaling, the need to calculate peak runoff for each event and scaling with size of field, this method is substantially harder to implement.

Valuation:

Described fully in the primary document.

Appendix 5: Phosphorus

Biophysical Quantities.

Our simulations of P loss utilize a slightly modified version of the Vermont Phosphorus Index. For simulating impacts of soil health, there are two sets of impacts. First, the reduced erosion rates reflect themselves in less soil lost through erosion. This is estimated simply by inputting the erosion rates for different soil-health scenarios into the P-Index model.

Second, improved soil health results in reduced growing-season runoff. To estimate these reductions in runoff, we first estimate curve-number adjustments from improved soil health based on runoff simulations used in the Flood Mitigation section and equations described by Baiamonte (2019) to translate the results of a Green-Ampt simulation into an approximate Curve number. These were combined with average rainfall data for Burlington, VT to estimate changes in total seasonal runoff. These results were translated into custom runoff adjustment factors for the P Index[7].

Otherwise, the P Index was parameterized as shown in Table S3.

Parameter	Value	Notes
Elevation	600	Most Vermont farm fields are at relatively low elevations
Soil Test Phosphorus ppm (Modified Morgans)	6	Considered a medium-high level. Crop fields in VT have a mean MM P of ~6.5 and a median of ~3 .
Soil Test Aluminum	40	Crop fields in VT have a mean Al level of 49 & a median of 31.
Tile Drain	Not Present	
Distance to water	25 feet	
Buffer Width	15 feet	

Table S 3: Parameters Used For the VT-P Index to calculate phosphorus losses

Valuation:

For the first method, we transfer the estimates of economic damages calculated for the Missisiquoi Bay by Gourevitch et al to other Lake Segments. To do this, we assume that the total economic damages of exceeding the TMDL for each Lake segment are determined by 3 quantities:

1: How much, in % terms, the segment's P Load exceeds the TMDL.

[7] Modifying the runoff adjustment factors found on page 6 of the VT P Index technical documentation.

2: The number of people living within 20 km of the Lake Segment (people living within 20 km of more than 1 Lake Segment are divided evenly between them.)

3: The average household income of the people living near that Lake Segment.

The second two quantities approximate the overall level of economic activity in the area; economic damages/benefits relating to ecosystem services are usually proportional to economic activity. A more exact calculation would use home-price and tourism revenue data.

For the first parameter, we find that a log-log model best fits the outputs of the base scenario and 6 different reduction scenarios from Gourevitch et al. We calculate the damage scaling factor M as (Figure S3):

$$M = (.721 + \ln(P_{base}/P_{tmdl}) \cdot .705)^{e}$$

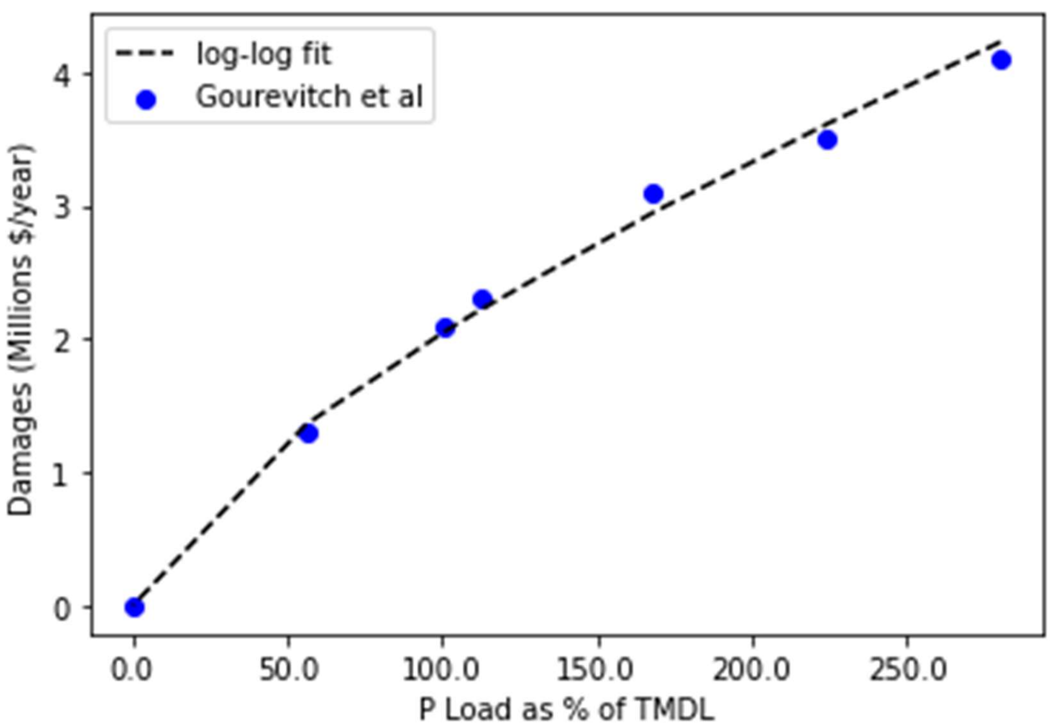

Figure S 3: Relationship between P Loading as a % of TMDL target and Total Damages, for the Missisquoi Bay in simulations run by Gourevitch et al.

For the 2nd and 3rd parameters, we use census block-group population data, and average household incomes for each county.

For each Lake Segment, we estimate total damages from Phosphorus as:

$$D_S = D_{MB} \cdot \frac{Pop_S}{Pop_{MB}} \cdot \frac{HHI_S}{HHI_{MB}} \cdot \frac{M_S}{M_{MB}}$$

And damages at the TMDL as

$$DTM_S = DTM_{MB} \cdot \frac{Pop_S}{Pop_{MB}} \cdot \frac{HHI_S}{HHI_{MB}}$$

Total Benefits from meeting the TMDL are calculated as:

$$B_S = D_S - DTM_S$$

Where D, DTM, P, HHI and are total damages from P, total damages from P if the TMDL is met, population within 20 km, household income, and damage scaler and the subscript S represents a given segment and the subscript MB represents the Missisquoi Bay.

The final valuation of Phosphorus is calculated as the benefit of meeting the TMDL divided by the required reduction.

This method yields the values shown in table S4 below. We calculate the average value of reducing a lb of Phosphorus from agriculture as the average weighted by the agricultural phosphorus load to each segment.

Segment	Phosphorus Valuation ($/lb)
Burlington Bay	678.83
Isle La Motte	83.86
Main Lake	16.39
Malletts Bay	38.21
Missisquoi Bay	10.35
Northeast Arm	71.92
Otter Creek	6.35
Port Henry	160.12
Shelburne Bay	111.09
South Lake A	76.99
South Lake B	18.43
St. Albans Bay	65.16

Table S 4: Valuation of Benefits from Reducing Phosphorus Losses, $/lb

Both methods used to scale up from the estimates made by Gourevitch et al are quite imprecise. Note as well that their paper was not exhaustive in its treatment of economic damages from water quality. Not included in their analysis are the “consumer surplus” from tourism/recreational activities, above the increased spending at local businesses, other health benefits from clean water, reduced costs for treatment of drinking water and reductions in risks of catastrophic changes in the ecology of Lake Champlain. We are not able to estimate how movement of Phosphorus between different Lake segments, rather than treating segments as distinct waterbodies, might impact the valuations given.

Counter-intuitively, Gourevitch et al show increasing marginal benefits from reducing phosphorus loads. If we calculate the price of phosphorus based on the total modelled benefit of reducing P loading to 0, then the valuation of phosphorus roughly doubles.

Comparisons:

Another way to conceive of the benefits reducing P loads is to consider VT’s obligation to meet the TMDL as a fixed commitment, and therefore, benefits of reducing P loads by 1 pound are the costs of the next cheapest alternative method. Using this approach would give a higher value than our damage-cost methods. The Vermont Pay-for-Phosphorus program currently pays $100/lb of P reductions, with substantial overhead costs. Costs of other opportunities to reduce P loads may be an order of magnitude higher. For instance, costs of reducing P from some VT wastewater treatment facilities are fairly low, but increasing these reductions see sharply increasing marginal costs (Figure S4). Additional reductions from urban areas or rural roadways may cost hundreds of dollars per lb of P.

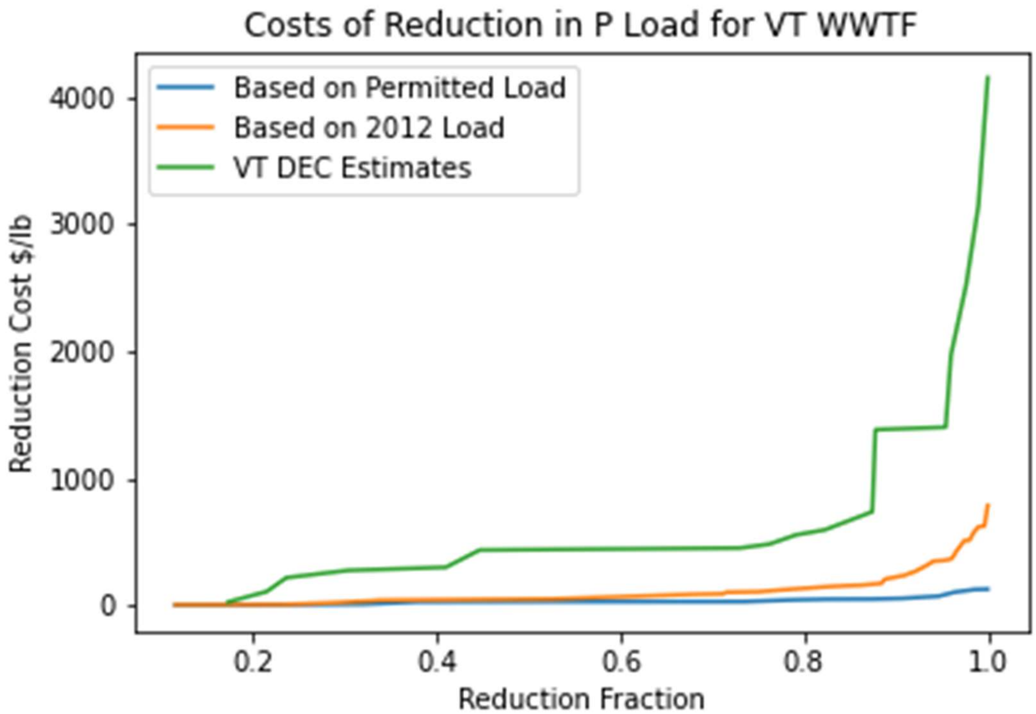

Figure S 4: Abatement Curves for Reducing Phosphorus Loads for Vermont Wastewater Treatment Plants.

Given that Vermont would not give up on the TMDL based on findings that the costs exceed the benefits, this approach might give a more realistic sense of the monetary benefits of reducing Phosphorus but understanding the exact costs of alternative measures may be difficult.

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The University of Vermont

Review of PES Programs

Vermont Payment for Ecosystem Services Technical Research Report #6

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

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The University of Vermont Extension

SECTION 1: INTRODUCTION

The review presented here aims to give an overview of Payment for Ecosystem Services (PES) program strategies both within the U.S. and abroad and highlight program strengths and weaknesses that can be applicable to Vermont agriculture. As described in their mission statement, the Vermont (VT) PES Working Group aims to develop a program that "envisions a system in which farmers are hired to use their ingenuity and know-how in caring for the land to rebuild Vermont's natural capital."[1]

At the time that this report was written, the PES Working Group was still considering basic program design elements, such as whether the system should compensate farmers for practices or for performance and how to quantify outcomes. This review was completed to assist the working group's framing of a VT-focused PES, as directed by the PES working group. Due to the large number of existing programs, the Task 6 research team compiled a concise yet thorough list of ten programs (in Section 2, we aimed to capture the prevalence of program components by describing how many of the programs out of the total demonstrate each component). These programs were chosen based on recommendations from within the working group and an emphasis on program diversity regarding location (international, US, Vermont), practice and performance, types of ecosystem service (ES), financial structure, and administration.

SECTION 2: PROGRAM REVIEW

2.1 PES Program Background

Payment for ecosystem services programs have grown in number and size in recent decades, but PES programs are still a developing concept and as such represent a comparatively young market.[2] All the programs reviewed in this report were launched in the last twenty years, with the majority beginning in the last decade (Table 1). Of the ten programs reviewed, BushTender in Australia is the oldest (2001). Sustainable Farming Incentive (SFI) in England and Vermont Pay for Phosphorus Program (VPFP) are the newest PES programs (2021) and are currently in pilot phases. The FCP began with a pilot group with land managers in 2009. FCP is well poised to be replicated and the project may still be considered in the pilot phase Table 1).

Four of the ten markets reviewed are outside the United States: SFI in England, Lake Taupo in New Zealand, BushTender in Australia, and Glastir in Wales, United Kingdom (Table 1). Two programs are national in scope, Natural Resources Conservation Service's (NRCS) government-run Conservation Stewardship Program (CSP) and Land O'Lakes' privately-run Truterra sustainability tool. Two programs, the Soil and Water Outcomes Fund (SWOF) and Lake Taupo, span a particular region. SWOF is available to eligible farmers in Illinois, Iowa, Ohio, and particular counties from states in the Chesapeake watershed (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia). The Lake Taupo program is available to landowners within the Lake Taupo catchment area of New Zealand. Three programs are state specific; California Healthy Soils Program (CA HSP), Vermont's FCP, and VT PFP.

[1] VT Agency of Agriculture, Food, and Markets, "Soil Conservation Practice and Payment for Ecosystem Services Working Group Report," 6, (January 15, 2020), https://legislature.vermont.gov/assets/Legislative-Reports/Soil-Conservation-Practice-and-PES-Working-Group-Report-01152020.pdf.

[2] Salzman, J., Bennett, G., Carroll, N. et al. The global status and trends of Payments for Ecosystem Services. Nat Sustain 1, 136–144 (2018). https://doi.org/10.1038/s41893-018-0033-0

Table 1. General Program Information

Program Name	Location	Year Founded	Primary Organization(s)	Financing[1]	Program Type
BushTender	Victoria, AU	2001	Dept. of Sustainability & Environment	Government	Voluntary
CA Healthy Soils Program (CA HSP)	California	2016[2]	California Department of Food and Agriculture	Compliance	Voluntary
Conservation Stewardship Program (CSP)	U.S. (nationwide)	2008	USDA NRCS	Government	Voluntary
Forest Carbon Project	Vermont	2009	Cold Hollow to Canada & Vermont Land Trust	Third-party	Voluntary
Glastir	Wales, UK	2009	Welsh Assembly Government	Government	Voluntary
Lake Taupo	Lake Taupo catchment area, New Zealand	2011	Lake Taupo Protection Trust	Government	Compliance with voluntary components
Soil and Water Outcomes Fund	Particular counties in Illinois, Iowa, Ohia, and the Chesapeake Watershed[3]	2019	AgOutcomes Inc. & ReHarvest Partners	Third party	Voluntary
Sustainable Farming Incentive	England	2021	Department for Environment Food and Rural Affairs	Government	Voluntary
Truterra	U.S. (nationwide)	2016	Land O'Lakes	Third-party and government	Voluntary
Vermont Pay for Phosphorus Program	Vermont	2021	Vermont Agency of Agriculture, Food and Markets	Compliance and Government	Voluntary

1. Financing is either categorized as third-party, government, or compliance where payments are made to farmers from third parties (direct beneficiaries and companies), government entities (typically through taxes), or compliance (regulations and enforcement penalties incentivizes participation).
2. Founded in 2016 due to 2015 CA Healthy Soils Initiative.
3. Eligible counties within the Chesapeake Watershed are in the following states: Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia.

2.2 Program Management
A variety of different entities own and manage the PES programs (Table 1). Most programs are government-run and voluntary. Two programs are managed by national government entities. Conservation Stewardship Program is managed by US government-run USDA-NRCS. Glastir is managed by the Welsh Assembly Government. Six programs are run by state entities, including the CA HSP and VT PFP. Another program is managed by a suite of NGO's, Cold Hollow to Canada and Vermont Land Trust's lead the FCP. The FCP is unique in that the carbon seller is an aggregate of landowners, not a single ES provider, as is with the other nine programs reviewed.

One program reviewed, Truterra, is privately owned. Truterra LLC is the sustainability business of Land O'Lakes. Truterra's sustainability tool is a modeling software platform that provides an avenue for both government agencies and privately owned corporations to provide payments that improve environmental health.

2.3 Program Market Scope
Nine of the programs reviewed are voluntary for the seller, meaning that the landowner is not required to participate (Table 1). The Lake Taupo program is compliance based, with some voluntary components. Five of the reviewed programs are open market (FCP, SWOF, SFI, and Truterra's). BushTender is a reverse-auction market. The Lake Taupo program is part of a cap-and-trade structure. The CA HSP program is funded by a cap-and-trade program, but like Glastir, CA HSP, and VT PfP, which are not market-based, are government conservation incentives (Table 2). Budgets for programs depend on the managing organization (Table 5). Government-run programs are funded by government funds with varying degrees of fiscal allotments. Some programs that may be government-run or privately-owned have received federal funding. For example, both SWOF and Land O'Lakes' Truterra have received grant awards from NRCS. The VT PfP program is entirely funded through NRCS.

All PES mechanisms are subject to some amount of market pressures or budget constraints. The BushTender and Forest Carbon Project are more vulnerable to market volatility as the link between buyer and seller is not strengthened by more predictable, significant government support. In the case of BushTender, the reverse auction scheme does not have a guaranteed price floor meaning that there is no minimum guaranteed payment and payment could be below the cost of investment. Comparatively, the FCP received some pilot funding from NRCS, Conservation Fund, and Landscape Scale Restoration (LSR) grants, but payment methods are dependent upon individual or corporate decision makers who are the buyers, similar to BushTender.

Table 2. Market Information

Program Name	Market Type	Buyer	Performance or Practice	Baseline or Threshold[1]	Ecosystem Services Paid For
BushTender	Reverse-Auction	Government	Practice	Baseline	Biodiversity (of native vegetation)
CA Healthy Soils Program (CA HSP)	N/A, government conservation incentives	Government and private companies	Practice	Baseline	Carbon sequestration and reduction of carbon, nitrous oxide, and methane emissions
Conservation Stewardship Program (CSP)	N/A, government conservation incentives	Government	Practice	Baseline	Various, based on state resource priorities
Forest Carbon Project	Open Market, Aggregate	Government, private companies, and individuals	Performance	Threshold	Carbon sequestration
Glastir	N/A, government conservation incentives	Government	Practice	Baseline	Biodiversity, soil, water, greenhouse gasses, woodlands, access, and recreation
Lake Taupo	Cap and trade	Government and other farmers	Performance	Threshold	Nitrogen loss reduction
Soil and Water Outcomes Fund	Open market	Government and private companies	Performance	Baseline	Carbon sequestration, nitrous oxide reduction, and water quality improvement (nitrogen and phosphorus retention)
Sustainable Farming Incentive	Open market	Government	Mix of practice bundling and monitoring	Baseline	Various, including pollinator habitat, downstream water quality, and enhanced soil conservation.
Truterra	Open market	Private companies	Performance	Baseline	Carbon sequestration
Vermont Pay for Phosphorus Program	Open market	Government	Performance	Threshold	Phosphorus loss reduction

1. When a payment is based on a 'baseline' it factors into account the additionality from improved or added agronomic practices. When a payment is based on a 'threshold' additionality is based on a defined standard.

Table 3. Program Details

Program Name	Required farm type (woodlot, dairy, veggie, farm of certain size, etc.)	Eligible Practices	Minimum Acreage	Other Eligibility Requirements	Contract duration
BushTender	Any landowner with native vegetation	At landowner discretion	n/a	Not specified	5 years, non-renewable
CA Healthy Soils Program (CA HSP)	Varies (Cropland, orchard, grazing)	Wide ranging, not limited to no-till, extended rotations, cover cropping, retiring land, wind barriers, etc.[1]	Not specified.	Applications must use the CDFA HSP Re-Plan Tool	3 years
Conservation Stewardship Program (CSP)	No required farm type	Various	None	Comply with USDA erodible and wetland provisions, exceed "stewardship threshold" for at least 2 priority resource concerns, have a Farm number registered with FSA, and receive <$900,000 annual AGI.	5 years
Forest Carbon Project	Woodlot	Not specified[2]	500 acres[3]	450 of the 500 acres enrolled must be forested	40 years[3]
Glastir	Owners of Agricultural land in Wales	Various	7.4 acres	Meet whole farm code and points threshold	5 years, renewable
Lake Taupo	Mainly sheep farms	Only controlled activities (larger-scale farming) eligible for NDA trading	By leaching rate instead of acreage	N/A	1 year, renewable
Soil and Water Outcomes Fund	Not specified	Various. Most common include: no-till, cover crops, land retirement, conversion to pasture, extended rotations	None.	Must be in eligible area and must be USDA compliant (in some geographies)	1 year, renewable
Sustainable Farming Incentive	No required farm type	Not prescribed	n/a	No existing agri-environment agreement and the land cannot be common land or used for shared grazing. Basic payment scheme applicant in 2020 or 2021.	3 years, renewable
Truterra	Not specified	Includes, but may not be limited to: cover cropping, reduced tillage, extended crop rotations	2.5 acres	Not specified	Varies by year, potential to renew
Vermont Pay for Phosphorus Program	Annual cropland or hayland (not pasture)	Not prescribed	n/a	Up to date NMP that meets the RAP standard for the farm size.	1 year, renewable

1. CA Healthy Soils solicits public to input new practices for payment consideration.
2. Implied eligible practices for the Carbon Forest Program include allowing trees to mature, managing for diverse types and age of trees and understory.
3. Typical forest carbon sequestration contract is 100 years.

2.4 Eligibility

Of the ten programs we reviewed, eight were explicitly for agricultural producers, one was for forest managers, and one was available to any landowner (Table 3, previous page). Seven of the programs specified eligibility requirements, including existing registration with governing bodies, compliance with environmental regulations, up-to-date management records, no prior program agreements, or minimum acreage. Three programs required a minimum acreage, one of which was the program concerning managed woodlots.

2.5 Pay for Practice or Pay for Performance

Half of the programs reviewed (FCP, Lake Taupo, SWOF, Truterra, and VT PfP) compensate land managers based on performance, all of which focus on ES like carbon sequestration or nutrient (nitrogen and/or phosphorus) reductions (Table 2). The remaining five programs (BushTender, CA HSP, Glastir, and SFI) were pay-for-practice. Regardless of payment based on practice or performance, there are a wide variety of eligible practices. Common accepted agricultural practices include reducing tillage, planting cover crops, extending rotations, and retiring land.

BushTender, Glastir, and CSP provide payment based on practice. CA HSP pays based on estimated cost of practice implementation, maintenance, and soil sampling over the project period. The SFI provides payment based on a mixture of practice bundling and monitoring. The programs reviewed aim to not be prescriptive and instead allow landowners to choose practices that best align with their farming system while working towards the PES program goals, though participants in some programs (notably Glastir) stated that they felt the program was administered in a way that was inflexible.

2.6 Required Data & Verification Methods

Payments are based on third-party verification of practice implementation or performance based on model predictions (Table 4). Six of the ten programs use modeling software with varying requirements for the amount and type of data the farmers must share to enroll in the program. However, three of the other four programs use geospatial modeling during the application process to determine the most efficient way to allocate resources. Seven programs measure outcomes against baselines. Those enrolled in the FCP can receive payments for exceeding thresholds and baselines. The initial forest carbon inventory is compared to a regional average. Payments for the length of the contract are based on the initial inventory baseline and the regional average threshold. If the landowners sequester more carbon above the initial inventory baseline they are compensated for that additionality. Six programs rely on third party verification—three of the remaining four are verified by government representatives, and the TruTerra program used third party verification after data collection. Seven programs verify annually. A verification schedule is unspecified for the other three.

2.7 Payments

In performance-based programs payments are provided based on a metric, such as lbs of phosphorus reduced from entering surface water, lbs/acre of nutrients retained, or tons/acre carbon sequestered (Table 5). In our review we found that four programs paid farmers on a per-acre basis, with payments ranging from \$19.49 to \$110 per acre across the programs; all four programs paid different per-acre rates to farmers based on specific practices, level of stewardship, and other variables. Two programs paid per unit of carbon and payment rates were dependent on market credits. SWOF paid for multiple ES provision, soil and water quality. The Lake Taupo program pays per unit of nitrogen reduced in runoff; the VT PFP similarly pays per unit of phosphorus reduced in runoff. Payments through the BushTender program varied according to the bid placed at the discretion of the farmer. Typical contracts for agricultural land managers range from 1-5 years. The FCP contract is for 40 years.

Table 4. Required data and verification method

Program Name	Data required	Baseline required	3rd Party Verification Required	Modeling Software	Verification schedule
BushTender	Landowner records	Yes	No, government verified	n/a	Annual
CA Healthy Soils Program (CA HSP)	Three years of baseline data	Yes	Yes, practices are verified by CDFA environmental scientists	CDFA HSP Re-Plan Tool	Annual
Conservation Stewardship Program (CSP)	Landowner records	Yes	No, government verified	n/a	Annual
Forest Carbon Project	Not specified	Yes	Yes	SIG Carbon provides modeling software	Annual
Glastir	Landowner records	No	Yes		Annual
Lake Taupo	All records and information needed to determine nutrient leaching cap by Overseer model. Annual accounting records to Regional Council.	Yes	Yes	Overseer (nutrient modeling)	1-2 checks per year
Soil and Water Outcomes Fund	Baseline and future cropping information	Yes	Yes, Data review conducted by Sustainable Environmental Consultants via the EcoPractices platform	COMET-Farm and Nutrient Tracking Tool	Annual
Sustainable Farming Incentive	Documentation of actions, supporting evidence, learning activities, annual declaration	No	Yes	n/a	Not specified
Truterra	Three years of baseline data	Yes	Yes, following data collection.	Various	Annual
Vermont Pay for Phosphorus Program	All nutrient and crop management info into FarmPREP for the upcoming season and updated by the end of the season.	Yes (TMDL)	Yes, provided by VACD	FarmPREP	Annual

Table 5. Payment information

Program Name	Payment range	Payment per unit	Other payments to producers
BushTender	Varies (undisclosed landowner bid); Determined through auction	Determined through auction	Initial upfront payment upon signing the Management Agreement
CA Healthy Soils Program (CA HSP)	Depends on the field type and practice. Range: $2.50/acre for adding perennial cover in strip cropping with annual crops to $30,683 for converting cropland to permanent unfertilized perennial vegetation near aquatic habitats with plug plantings. See HSP Application guidebook for detailed payment structure guidebook for more examples.	$/acre	Not specified
Conservation Stewardship Program (CSP)	NRCS pays a minimum $1,500 per year and a maximum of $40,000 per year	Payments vary by state and are allocated on a per acre basis	None
Forest Carbon Project	$25-47 per acre	Not specified	In some cases, CHC can help minimize legal fees and baseline documentation which can range between $11,000-15,000.
Glastir	US $19.49 per acre	US $19.49 per acre	Increased rates for farmers in different Glastir Elements, as well as a per acre payment under the Whole Farm Code.
Lake Taupo	Approx. $400/kg of N	$/kgN	Costs of benchmarking (similar to enrollment) and subsequent measuring and monitoring covered by Lake Taupo Protection Trust
Soil and Water Outcomes Fund	Average 2021 payment was $31/acre. Payment max is $40/acre.	Not specified	Not specified
Sustainable Farming Incentive	£16-50 introductory, £30-90 intermediate, £35-110 advanced	Hectares and meters	Learning activities and capital items
Truterra	$20/ton/year	$/ton C	In some cases, initial data entry.
Vermont Pay for Phosphorus Program	Not yet specified	$/lb P	Initial data entry payment of $15 per acre up to a $4,000 cap.

SECTION 3: DISCUSSION

There are hundreds of watershed-related PES systems globally and new programs continue to be developed.[3] The high number of existing PES programs compensating land managers for their ecosystem service provisions suggests that this can be an effective strategy for rebuilding natural capital and the variety of existing PES programs indicates that there is no single answer to how a VT PES program should look. This level of program diversity reflected in this project can provide the working group with opportunities to mix and match applicable and successful components of past PES work.

a. Fairness

The working group identified fairness as a priority for designing a PES program. Through this review, we found that program fairness was determined by different approaches to access, communication, and eligibility.

i. *Access*

Programs can be unfair if payments are not designed to accommodate the varying financial needs of different farms. Entering a market could require investing in new infrastructure or equipment when transitioning to conservation agronomic practices, which will prevent farmers with low capital from participating.

Not only could this discourage participation by farms that could benefit most from a new revenue opportunity, but distinct groups—like new or historically underserved farmers—will be disproportionately excluded. Some programs take steps to address this issue, like CSP which includes a higher ranking to beginning and socially disadvantaged farmers and reserves 5% of funding for each of these groups.[4] VPFP includes a similar ranking priority to historically under-resourced groups, defined in this case as a group whose members have been subject to racial or ethnic prejudice because of their identity as members of a group without regard to their individual qualities[5].

Small farmers, defined by the Agency of Agriculture, Food, and Markets (AAFM) as farmers who operate on less than 50 acres[6], may also be at a disadvantage to compete for participation with larger farms that can distribute costs of new conservation practices over more units of production. Vermont PfP makes mention of prioritizing applicants from a diversity of sizes and locations but does not go as far as indicating a change in pay rate based on this. Programs that offer different rates for smaller farms can help address this kind of issue, such as was described in the Gund Institute's proposal presented to the Vermont PES Working Group on September 30, 2019 (the Gund proposal is not included in this review).[7] Conversely, payments need to be large enough to entice large farms to enroll. Farms with large land bases, managing significant volumes of ES resources, may see the copious amount of time to enter detailed data for every field as a significant barrier to investing their time and farm in the program. For example, the VT PfP data entry incentive of $15/acre compensates data entry, but is capped at $4,000.

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[3] Salzman, James, G. Bennett, N. Carroll, A. Goldstein, and M. Jenkins. "The global status and trends of Payments for Ecosystem Services." *Nature Sustainability*, vol. 1, no. 3, Mar. 2018, pp. 136–144., https://doi.org/10.1038/s41893-018-0033-0.

[4] NSAC, "Farmers' Guide to the Conservation Stewardship Program; November 2020 edition," 44-45 (2020), https://sustainableagriculture.net/wp-content/uploads/2020/11/CSP-2020-draft3-interactive-1-1.pdf.

[5] NRCS. (n.d.). Historically Underserved Farmers & Ranchers. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/people/outreach/slbfr/?cid=nrcsdev11_001040

[6] Agency of Agriculture, Food, and Markets. (2021). *Farm Size Classifications*. https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/FarmSizeClass.pdf

[7] VT Agency of Agriculture, Food, and Markets, "Soil Conservation Practice and Payment for Ecosystem Services Working Group Report," 21-31, (January 15, 2020).; Courtney Hammond Wagner et al., "Payment for Ecosystem Services for Vermont," *Gund Institute for Environment*, 24, (2019).

Likewise, CSP's limit of $40,000 per year and could dissuade some larger-operating farms from participating.

Additionally, some studies show that participation rates in conservation programs can be negatively affected by farmer-resistance to government run programs—even among farmers who expressed support for targeted conservation approaches—indicating that a program may be less accessible if it ifsimplemented by a government[8] (this should be considered with respect to our recommendation that a VT PES program should be government run, *see below*). To overcome farmer-resistance to government programs, programs should be designed to be more "palatable" to farmers by working to build relationships and establish trust,[9] which is in part addressed in the other recommendations of the synthesis.

ii. Communication

Proper communication and publicization also affect PES accessibility by determining whether all potential applicants receive accurate information.[10] The Glastir program in particular received negative feedback from participants about poor communication strategies that left farmers feeling unsupported, and Glastir reported low-participation rates as a result. Additionally, CSP remains under-enrolled in Vermont in part because the program is poorly suited to the state's unique farming sector, but also because many farmers have misconceptions about the program eligibility because of ineffective publicization.[11]

Additionally, programs that offer access to technology (i.e. modeling software) or trained assistance with data entry can further reduce barriers and providing well trained and accessible technical assistance can increase enrollment and program participation. For example, Lake Taupo, and VT PFP programs provide staff to help farmers enter data and provide training about the software to farmers. Truterra retailers assist farmers in data collection and ongoing conservation planning assist farmers in data collection and ongoing conservation planning. CA HSP made considerable investment to streamline its application software.

iii. Eligibility

The Working Group's initial report to the Legislature states that their aim is to design a VT PES program that "[ensures] all farms, regardless of size, geography or product, have the opportunity to participate."[12] Some programs use eligibility requirements to target specific outcomes (FCP, Lake Taupo, Vermont PfP). While this approach can help allocate resources it also limits program participation. Other programs prioritized inclusivity by setting low eligibility requirements to encourage participation (Glastir, CSP).

However, inclusivity can be limited by available resources (as with CSP), which can compromise the program's fairness. Several programs with resource limitations used a ranking scheme (as in CSP and BushTender) to allocate resources to those farms that could produce the highest proportion of resource returns to investment (NRCS' CART ranking tool—used for CSP—also considers a higher ranking for historically underserved farmers, rather than strictly

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[8] Kalcic, M., Prokopy, L., Frankenberger, J., & Chaubey, I. (2014). An in-depth examination of farmers' perceptions of targeting conservation practices. *Environmental Management*, *54*(4), 795-813.

[9] *Id.*

[10] Equiterre and The Greenbelt Foundation, "The Power of Soil: An Agenda for Change to Benefit Farmers and Climate Resilience," 13 (no date), https://d3n8a8pro7vhmx.cloudfront.net/greenbelt/pages/14625/attachments/original/1614349880/PowerOfSoil.pdf?1614349880.

[11] Conversation with Joe Buford, Vermont State Resource Conservationist, during Vermont Small Farm Group Meeting on October 20th, 2021.

[12] VT Agency of Agriculture, Food, and Markets, "Soil Conservation Practice and Payment for Ecosystem Services Working Group Report," 8, (January 15, 2020).

environmental objectives. *See above*).[13] Only those farms that were ranked high enough to be included before funding ran out were included in the program. Vermont's PES program will likely have resource limitations, meaning that complete fairness might not be possible, and administrators and participants will need to have "hard conversations" about inclusivity and funding.[14]

b. Practice vs. Performance Based Payments

Although the measurements of a performance-based program offer greater certainty about the program's success and can give farmers greater autonomy, the equipment and labor for monitoring outcomes can be prohibitively expensive.[15] While the programs in this review cover an almost-even mix of practice and performance-based programs, the majority of existing programs are practice based because of the difficulty and expense of quantifying outcomes.[16] The performance based programs covered in this review addressed these barriers by using model, or a mix of models and measurements, to project rather than directly measure outcomes.

Therefore, if the Vermont PES Working Group decides to pursue a performance-based program, they are more likely to succeed if they use models to measure outcomes. This was already suggested by the Vermont Dairy and Water Collaborative (VDWC) in their 2019 Call to Action, where they found that "the method for measuring results needs to be carefully considered and requires further work. On-the-ground monitoring is prohibitively expensive, and models are limited by their base assumptions."[17] VDWC suggested following a mix of monitoring and modelling like that of the Lake Taupo Protection Trust nitrogen program in New Zealand. Program administrators set nitrogen discharge allowances for farmers based on individual farmer baselines and overall nitrogen reduction goals, both modelled through a software called Overseer. These nitrogen discharge allowances could be traded, changed annually through management practices, or sold to the Lake Taupo Protection Trust. Aspects of this program may be applicable for the VT PES, if ecosystem services are able to be measured through accurate software, and a fair price set for their provisioning. This would be an advantage of a performance-based payment system by providing a method of measurable. Refer to Table 5 for examples of payments based on measured outcomes.

Several programs—especially those that were administered by government, like CSP, Glastir, and BushTender—maintained low administrative costs and offered secure payments to farmers by only verifying practice implementation. The CA HSP uses a model to quantify performance, but also pays for the cost of soil sampling. In this way a program could reduce risk and cost by using a model and improve the accuracy of a model by collecting real world data from a selection of participating farms. We also feel it is important to note that the pay-for-practice programs are well-established, whereas standard structures for pay for performance programs are still in development.

Practice-based and performance-based programs have different effects on risk placement.[18] Practice based programs offer secure payments to farmers who successfully implement practices, and place the risk on the ecosystem service buyer (State of Vermont) that the practice may not

[13] NSAC, "Farmers' Guide to the Conservation Stewardship Program; November 2020 edition," 44-45 (2020), https://sustainableagriculture.net/wp-content/uploads/2020/11/CSP-2020-draft3-interactive-1-1.pdf.
[14] Webinar presented to the VT PES Working Group by James Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.
[15] Vermont Dairy and Water Collaborative, "A Call to Action," 27, (March 15, 2019), https://www.vtfarmtoplate.com/assets/resource/files/VDWC%20Final%20Report%20Compilation.pdf
[16] Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.
[17] Vermont Dairy and Water Collaborative, "A Call to Action," 27, (March 15, 2019), https://www.vtfarmtoplate.com/assets/resource/files/VDWC%20Final%20Report%20Compilation.pdf.
[18] Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

deliver the expected outcomes—in essence, the buyer enters the agreement with strong confidence that their modelling tool and research is accurate enough to identify which practices will achieve the desired outcomes.[19] In comparison, a performance-based program may place a high level of risk on the farmer if their management strategy fails to deliver the desired outcomes.[20] In some cases, the farmer may not achieve the desired outcomes because of factors outside the farmer's control, such as an abundance or absence of rain.[21] The Vermont PfP program partially addresses these issues by offering an enrollment payment. Farmers enrolled in the program will be paid per acre to enter relevant field data into the FarmPREP software, regardless of future performance.

c. Credibility

Credibility of the PES program is necessary for program success. The public and potential participants must trust that the institution(s) administrating the program is trustworthy, fair and uses sound verification methods. The institution(s) cannot be seen as giving any special favor or disfavor to any individual participant or groups of participants.

Several of the programs administered by governments are assumed to be credible because they can be held accountable through democratic processes (CSP, Glastir, Vermont PfP, etc.). Some programs used third-party verifiers (Lake Taupo, SWOF, Vermont PfP) or use third party verifiers after initial data collection (Truterra) to ensure credibility. Additionally, programs aimed to maintain trust and fairness by using the best measuring and modelling, such as Vermont's investment in developing the Farm-PREP tool used for the Vermont PfP program[22].

d. Longevity

Another aspect for the working group to consider is longevity.[23] Farmers will be taking certain risks when participating in these programs and changes in government policy or loss of government support have been identified as key risk factors that affect farmer engagement in conservation programs.[24] A guarantee of program longevity will enhance farmer ability to cover liabilities like investments in new equipment and time to learn alternative management systems or yield losses from new management approaches. A long-term funding stream is necessary to ensure longevity, so many of the programs use a multi-year contract (CSP, Glastir, BushTender, FCP, SFI).

e. Regulation

PES programs operate within a market and require a driver of demand. Demand for ecosystem services is largely created through regulation because the services are externalized in traditional markets and are not subject to physical scarcity or social demand.[25] Many PES programs (like Glastir, CSP, SFI, VT PFP, Lake Taupo, and BushTender) are therefore directly administered by a

[19] Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

[20] Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

[21] Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

[22] Agency of Agriculture, Food and Markets. (2021). *The Vermont Pay-For-Phosphorus (VPFP) Program Overview*. https://agriculture.vermont.gov/sites/agriculture/files/documents/VPFP_Overview_FAQs.pdf

[23] Byrne, J., Bonasia, C., and White A. Focus groups with Vermont farmers in spring 2021. Unpublished data.

[24] Greiner, R., Patterson, L., & Miller, O. (2009). Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural systems*, *99*(2-3), 86-104.

[25] Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

government entity.[26] This indicates that the PES Working Group's aim to design a program administered by a state agency is a good option.

As noted above, administering the program through a government does have some challenges caused by farmer mistrust of government regulation and implementation, and these challenges will need to be overcome by building relationships and establishing trust.[27] Research finds that this mistrust was largely generated by skepticism about the objective of implementing the practices, suggesting that better communication of the program goals can help improve participation.[28]

f. Baselines or Thresholds?

There are trade-offs of additionality and fairness between programs that use baseline or threshold measurements to determine compensation. Threshold measurements pay all farmers meeting a degree of stewardship, which is fairer but also costs more for the administrator to achieve additional outcomes. Furthermore, payments based on thresholds have the potential to result in no additional ecosystem service benefits on farms that are already providing those benefits anyway and could instead only regard those farmers that have not practices good stewardship. Baselines ensure outcomes but don't compensate those who have already achieved high stewardship levels.[29]

CSP aimed to target compensation to good land stewards by requiring participating farms to already exhibit and meet stewardship thresholds for at least two resource concerns. Glastir similarly required farms to display good stewardship but took the added step of providing 10% greater compensation to farms willing to accept a conservation plan with a more limited range of eligible practices that were targeted to regionally-specific resource concerns—this also helped address disparities in applying threshold measurements for varying conditions between farms, like location, crop type, or soil series. The SFI and VT PfP programs similarly set thresholds to account for farmers' existing stewardship. In VT PfP, the threshold is set as the Lake Champlain Basin phosphorus TMDL reduction requirements. Additional reductions beyond this threshold will be paid per pound of phosphorus reduced. In SFI, farmers select certain standards, which can also be thought of as thresholds, and associated practices to try and achieve. For example, a certain standard may include cover cropping a % of land, reduction in tillage, and executing a nutrient management plan. If a farmer was cover cropping and completing nutrient management plans prior to the SFI, they will need to implement fewer actions to achieve the standard and will receive payment for actions they were already doing.

SECTION 4: PES PROGRAM RECOMMENDATIONS

Based on discussions with the working group as well as the program review, we have identified certain components of a successful PES programs. These include:

a) prioritizing fairness;

b) hybridizing compensation in a tiered approach to include pay for practice and performance;

c) establishing credibility;

d) guaranteeing longevity; and,

[26] Salzman James, et al., "The Global Status and Trends of Payments for Ecosystem Services," Nature, 140 (2018).; Webinar presented to the VT PES Working Group by Jon Winsten, Winrock International, (10/13/2019), https://www.youtube.com/watch?v=LajIazIPHmM.; Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

[27] Kalcic, M., Prokopy, L., Frankenberger, J., & Chaubey, I. (2014). An in-depth examination of farmers' perceptions of targeting conservation practices. *Environmental Management*, *54*(4), 795-813.

[28] *Id.*

[29] Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8.

e) administering through a government to create demand through regulation.

f) Additionally, determining whether to measure from a baseline or threshold will also influence a program's success, but various other factors need to be established before deciding which option is best. A cost-benefit analysis is needed that examines the trade-offs between specific program goals and resource constraints. This would impact the number of farmers enrolled, acres with implemented practices, or number of units reduced or retained.

Farmers care about being supported and compensated fairly for involvement in agri-environment programs. One of the programs we reviewed—Glastir—is being replaced partly in response to participants dissatisfied with the programs poor technical support and communication.[30] Similarly, pilot testing of the Sustainable Farming Incentive program has identified issues with the application process and guidance as areas of concern. Further, out of the initial 938 farmers enrolled in the program, over 700 have already reached out to the administering body for support with the application and project implementation. The Vermont PES Working Group should emphasize the importance of technical assistance, communication, and trust in program design for Vermont.

PES programs that pay for performance can complement other payment for practice programs like the USDA NRCS EQIP. It is the responsibility of the administrating institutions to provide outreach to potential participants through trade-offs among different programs. We recommend that as a part of PES publicization efforts, potential participants are aware of program enrollment rules including which programs can accommodate dual enrollment (for example, land enrolled in EQIP can be enrolled in CSP, but CSP cannot pay for practices already covered by EQIP). Some programs highlight their compatibility with other agri-environment schemes, such as VT PfP, while others may prohibit dual enrollment as part of their eligibility requirements, like the SFI program in England.

Payment for practice may be considered unfair to farmers who have exceeded the standard. Conversely, payment for performance may be considered unfair to farmers who have not had sufficient investment support to implement conservation practices (typically small farms and other historically underserved farmers). Therefore, where resource and budgetary constraints allow, we recommend a tiered hybrid approach where farmers are paid for both practices and outcomes. By paying for practices, the administering body takes certain financial risks away from the farmer who is meeting conservation standards. By paying for performance, farmers are compensated for exceeding the standard.

Successful PES programs often include incentive payments for things such as enrollment, data entry, and learning activities. The BushTender, CSP, and Glastir all had the support of federal or regional governments and therefore enjoyed strong capacity, credibility, secure data management and easy verification of practices. As mentioned earlier, the VPFP program offers an enrollment payment to farmers of $15/acre up to $5,000 simply for data entry into the program modelling software. The FCP partners with other organizations to offer to help minimize legal fees and baseline documentation, the cost of which can range between $11,000-$15,000.

Furthermore, some programs indicate a stronger chance of success when pursuing multiple objectives (social, economic, etc.) in addition to environmental outcomes.[31] Particular to Vermont, the program may add to its chance of success by also pursuing the Working Group's objective to use the PES program to help achieve parity in the agriculture sector by compensating farmers for their stewardship of ecosystem

[30] Llywodraeth Cymru, " Co-design for a Sustainable Farming Scheme for Wales," 33-39 (2021), https://gov.wales/sites/default/files/publications/2021-09/sustainable-farming-scheme-co-design-future-farming_0.pdf.
[31] Heidi R. Huber-Stearns et al, "Social-ecological enabling conditions for payments for ecosystem services," Ecology and Society (2017), https://www.jstor.org/stable/pdf/26270112.pdf.

services[32][33] Though several of the programs evaluated in this project focus strictly on environmental outcomes, like BushTender, programs like CSP were partially established to support the agriculture sector by" [offering] farmers the opportunity to earn payments for actively managing, maintaining, and expanding conservation activities."[34]

To address issues of fairness, any PES program implemented should be widely publicized and be open to all farms regardless of farm type, size, or location. Additional effort should be made to reduce barriers to entry and participation in the program for farmers who are owners of small operations, first generation, or are historically underserved. We also want to acknowledge that there are multiple pathways to providing environmental outcomes. As Engle, Pagiola, and Wunder wrote, "PES is not a silver bullet...but a tool tailored to address a specific set of problems: those in which ecosystems are mismanaged..." [35]

Carefully crafted program design and outreach can help to avoid unintended consequences. PES programs have been framed by some organizations as a "false solution" to environmental issues.[36] By quantifying and selling natural capital, these organizations say that PES programs do not transition away from "extractive industries," rather than buy into the same system that allowed the market failure.[37] Furthermore, PES programs may also continue to undermine small farmers and maintain power imbalance if not strategically designed with those pitfalls in mind.[38] Overemphasis on designing for individual additionality and efficiency can cause new externalities and crowd out intrinsic stewardship motivations.[39] However, programs that frame PES payments through the lens of a reward or compensation for stewardship, offer flexibility in supported activities, and address multiple ecosystem service targets have been documented to reinforce stewardship identities and promote long term shared responsibility for ecosystem health.[40]

SECTION 5: CONCLUSION

The strengths and weaknesses exhibited by the wide variety of existing programs offers the Vermont PES Working Group an opportunity to explore other PES approaches to date. While many factors still need to be decided, the outcomes of this review indicate that a Vermont PES program is most likely to succeed in line with the Working Group's goals if it prioritizes fairness, compensates for a hybridized approach of paying for practices and performance, establishes credibility, guarantees permanence, and is administered by a government.

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[32] VT Agency of Agriculture, Food, and Markets, "Soil Conservation Practice and Payment for Ecosystem Services Working Group Report," 13, (January 15, 2020).
[33] Webinar presented to the VT PES Working Group by Jim Salzman, UC Santa Barbara, (11/1/2019), https://www.youtube.com/watch?v=Tv6mU6lSql8. *Salzman considers targeting farm viability through his discussion on 'wealth distribution.'*
[34] NSAC, "Conservation Stewardship Program," (updated April 2019; access 10-29-21), https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/conservation-stewardship-program/.
[35] Engle, Stefania, S. Pagiola, and S. Wunder. "Designing payment for environmental services in theory and practice: An overview of the issues," *Ecological Economics*, 663-674 (2008).
[36] Tamra Gilbertson, "Carbon Pricing: A Critical Perspective for Community Resistance," Indigenous Environmental Network & Climate Justice Alliance, 5, (2017).; Also see Richard Conniff, "What's Wrong With Putting a Price on Nature?," Yale Environment 360, (2012), https://e360.yale.edu/features/ecosystem_services_whats_wrong_with_putting_a_price_on_nature.
[37] Tamra Gilbertson, "Carbon Pricing: A Critical Perspective for Community Resistance," Indigenous Environmental Network & Climate Justice Alliance, 5, (2017).; Also see Richard Conniff, "What's Wrong With Putting a Price on Nature?," Yale Environment 360, (2012), https://e360.yale.edu/features/ecosystem_services_whats_wrong_with_putting_a_price_on_nature.
[38] *Id.*
[39] Chan, K. M., Anderson, E., Chapman, M., Jespersen, K., & Olmsted, P. (2017). Payments for ecosystem services: Rife with problems and potential—for transformation towards sustainability. *Ecological Economics*, *140*, 110-122.
[40] *Id.*

APPENDICES (click to link directly to specific program)

Appendix I: BushTender

1. Basic Program Information

- **Program name:** Bush Tender[1]
- **Program location:** Victoria, Australia[2]
- **Year founded:** 2001[3]
- **Size of program (# of farms, landowners, etc.):** 89 (in 2012)[4]
- **Acreage of program:** 87,107.12 acres (35,251 hectares)[5]
- **Minimum acreage required**: There is no minimum size for a site to be eligible.[6]
- **Program administrator**: Government of Victoria[7]
- **Targeted participants:** Victoria landholders with native vegetation on their land[8]
- **Prerequisites for enrollment:** Any landholder with pre-existing natural vegetation[9]
- **Required data sharing**: Information gathered during site assessment.[10]
- **Budget (overall, annual, etc.):** Approximately ranging from AU$1.9 to >AU$2 million per year (based on 2012 information)[11]
- **Funding source/who pays:** Government of Victoria[12]
- **Duration of program:** Either a 5 Year Management Agreement *or* a 5 Year Management Agreement plus a Permanent Protection Agreement.[13]
- **Goal/expected outcome(s): Increase** in biodiversity of native vegetation[14]
- **Specific conservation practices mentioned/measured:** Practices are at the discretion of the landowner/field representative.[15]
- **Ecosystem services measured**: Native Vegetation/ Biodiversity. Specific metrics vary.[16]
- **Method of ecosystem services measurement**: Practices are verified through self-reporting by the farmer, preferably with a photographic record.[17] A habitat hectares methodology is used to assess vegetation condition.[18]

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[1] Victoria State Government, "BushTender," Environment, Land, Water, and Planning, (last updated 25/07/2019), https://www.environment.vic.gov.au/innovative-market-approaches/bushtender. [*hereafter* BushTender Homepage]
[2] *Id*.
[3] *Id*.
[4] John Rolfe, Stuart Whitten, and Jill Windle, "The Australia Experience in Using Tenders for Conservation," Land Use Policy, 63 (2017). [*hereafter* Rolfe et al.]
[5] *see* BushTender Homepage.; *The Victoria Government also measures the program by Habitat Hectares (HHA), "defined as a site-based measure of quality and quantity of native vegetation that is assessed in the context of the relevant native vegetation type." Total HHA for BushTender is 5,560.*
[6] Department of Sustainability and Environment, "BushTender: Frequently Asked Questions," (2009), http://www.dse.vic.gov.au/__data/assets/pdf_file/0010/100162/BT2009_Information_sheet_2_-_frequently_asked_questions.pdf. [*hereafter* BushTender FAQ]
[7] *Id*.
[8] Department of Sustainability and Environment, "BushTender: General Information—Information Sheet No. 1," (2011), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1016886. [*hereafter* Info Sheet 1]
[9] *Id*,
[10] Department of Sustainability and Environment, "BushTender: The Site Visit—Information Sheet No. 3," (2007), https://www.vgls.vic.gov.au/client/en_AU/search/asset/1012331/0. [*hereafter* Info Sheet 3]
[11] *see* Rolfe et al. at 63.
[12] *Id*.
[13] Department of Sustainability and Environment, "BushTender: Frequently Asked Questions—Information Sheet No. 2," (2009), http://www.dse.vic.gov.au/__data/assets/pdf_file/0010/100162/BT2009_Information_sheet_2_-_frequently_asked_questions.pdf.
[14] *see* BushTender FAQ
[15] *Id*.
[16] *see* Rolfe et al. at 63.
[17] Department of Sustainability and Environment, "BushTender: Photopoint Monitoring—Information Sheet No. 17," (2008), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012712.
[18] Convention on Biological Diversity, "Bush Tender Programme," (date estimated to be 2012) https://www.cbd.int/financial/pes/australia-pesbush.pdf. [*hereafter* CBD]

Appendix I: BushTender

1. **Basic Program Information (cont.)**
   - **Practice or performance**: Practice (performance is recorded, but payments are based on a budget for practices)[19]
   - **What is paid for**: A proposed budget for new practices to implement a conservation plan.[20]
   - **Payment (cost) per unit of service**: Variable, depends on bidding process.[21]
   - **Payment mechanism**: Initial upfront payment upon signing the Management Agreement, with annual payments made following completion of agreed actions. Payments are made directly to the Landholder by cheque or electronic funds transfer[22]
   - **Average payment**: Variable, depends on bidding process.[23]
   - **Total payments/percentage of budget towards payments**: Not specified
   - **Selling point/tagline**: Not specified

2. **History/Brief Overview**

BushTender is a voluntary incentive-based program that "is aimed at improving the quality of native vegetation and its value as habitat for rare or threatened plants and animals."[24] The program is one of several market-based incentive programs used to achieve environmental objectives in Australia, with others including the EcoTender Programme and the Environmental Stewardship Programme.[25]

BushTender uses a reverse auction system through which landholders submit bids for government investment in return for providing improved biodiversity outcomes.[26] Investments are allocated to landholders who can provide the greatest economic return relative to the investment.[27] Chosen landholders receive periodic payments for management activities under a 5 year agreement with the Victorian Government. BushTender supports landholders to "[manage] native vegetation that is above their current obligations and legislation."[28] There is no minimum size for a site to be eligible.[29]

3. **Program Process**

Details of application, prerequisites, baseline assessments, objectives, payment calculation, etc.

i. *Expression of Interest*[30]

Landholders with native vegetation on their land can submit an "expression of interest" to the Department of Land, Water and Planning (DELWP). The Department stops accepting expressions of interest when "participation levels are considered sufficient."

[19] Department of Sustainability and Environment, "BushTender: Bidding Process—Information Sheet No. 5," (2008), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012721. [*hereafter* Info Sheet 5]
[20] *Id.*
[21] *Id.*
[22] *see* BushTender FAQ.
[23] *Id.*
[24] *see* BushTender FAQ
[25] *see* CBD.
[26] *Id.*
[27] *see* Rolfe et al. at 63.
[28] *see* BushTender Homepage.
[29] *see* BushTender FAQ.
[30] *see* Info Sheet 1.

Appendix I: BushTender

3. Program Process (cont'd)

ii. *Site Assessment*[31]

Site Assessments are conducted by Field Officers who conduct vegetation and habitat quality assessments. The Field Officer and landholder then discuss possible management options. The specific parameters assessed are:

a. Biodiversity Significance Score: This score reflects the conservation significance of each site. The score is based on 1) distinct native vegetation sites on the property, 2) conservation status of vegetation on the site, 3) vegetation quality as indicated by site conditions and landscape context (e.g., presence of old trees and healthy tree canopy, size of vegetation patch), 4) significance of vegetation in the broader landscape (e.g., opportunity for connection habitats), and 5) native plant and animal species likely to be present, based on information from the DSE database.

b. Habitat Services Score: This score measures of the potential improvements in for natural vegetation following management commitments and actions. The score is based on 1) commitments to protect the current site quality, 2) actions to improve site quality, 3) amount of area proposed for management, and 4) the length of the agreement.

iii. *Development of draft Management Plan* [32]

After the site assessment, the landholder receives a BushTender approved draft Management Plan developed from discussions with the Field Officer, along with information that will help the landholder manage the existing native vegetations. If the landholder wishes to make changes to the plan, they should contact the BushTender Regional Implementation Manager as soon as possible to discuss changes, which must be discussed before an approved bid is place.

iv. *Submission of Bid* [33] [34] [35]

Landholders may place one bid per site assessed. The price of the bid is entirely determined by the landholder to balance the current biodiversity values of their site against the costs of implementing the plan, like labor costs, materials, risk, and new or emerging threats.

The landholder can consider the current biodiversity field values of their site as communicated by the Field Officer. Landholders can improve the likely success of their bid by agreeing to the broadest range of commitments and management actions, increasing the area covered by the bid, identifying threatened plants or animals on the land, and authorizing program officials to record any threatened species found during assessment.

Multiple landholders can submit a joint bid together. In this case, a single party will represent the group and will be accountable for the delivery and reporting on management actions.

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[31] *see* Info Sheet 3.
[32] Dept. of Sustainability and Environment, "BushTender: Grasslands: Specifications for Management—Information Sheet No. 5," (2011), https://www.vgls.vic.gov.au/client/en_AU/search/asset/1146063/0.
[33] Department of Sustainability and Environment, "BushTender: Submitting a bid—Information Sheet No. 12," (2008), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012728.
[34] *see* Info Sheet 5.
[35] Department of Sustainability and Environment, "BushTender: Group Participation—Frequently Asked Questions—Information Sheet No. 18," (2011), https://www.vgls.vic.gov.au/client/en_AU/search/asset/1017705/0.

Appendix I: BushTender

3. **Program Process**

v. *Bid Assessment*[36] [37]

After all participants submit their bids, an evaluation team compares the bids against each other. "This comparison will include consideration of the biodiversity values of the site, the expected biodiversity outcomes resulting from the proposed commitments and management actions, and the bid price." The evaluators use a *Biodiversity Benefits Index* calculated for each bid, which quantifies the conservation significance for each site, expected outcomes, and the bid price.

> Biodiversity Benefits Index = (Biodiversity Significance Score X Habitat Services)/ (Score Bid Price submitted by landholder)

Bids are then ranked according to their Index score and funds are allocated to those plans representing the greatest "value for money."

vi. *Details of actions by participants/funder.*

If a bid is accepted, the farmer implements the proposed plan and submits annual reporting. Because specific practices vary according to each bid, participant actions are unique to each site.

vii. *Detail of monitoring, reporting, payment process.* [38] [39]

Reporting is done annually and is conducted by the landholder. Landholders submit a report describing 1) site details, 2) management actions and commitments, 3) action status, and 4) action descriptions, as well as 5) any comments or observations of unexpected outcomes, etc. Landholders are also encouraged to submit photographs to provide a visual record of land improvements.

3. **Concerns/Issues**

Pre-existing land stewardship values drive a tendency of landholders to underbid in reverse auctions, leading to inadequate compensation for management changes.[40] This can have an additional "crowding-in" ("leveraging and increasing non-monetary motivations to participate") effect.[41]

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[36] *see* Info Sheet 5.

[37] Department of Sustainability and Environment, "BushTender: Assessment of Bids—Information Sheet No. 6," (2007), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012334.

[38] Department of Sustainability and Environment, "BushTender: Annual Reporting—Information Sheet No. 16," (2008), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012732 .

[39] Department of Sustainability and Environment, "BushTender: Photopoint Monitoring—Information Sheet No. 17," (2008), https://vgls.sdp.sirsidynix.net.au/client/search/asset/1012712.

[40] Chan et al., "Payments for Ecosystem Service: Rife with Problems and Potential—for Transformation towards Sustainability," Ecological Economics, 10 (2017), https://open.library.ubc.ca/soa/cIRcle/collections/facultyresearchandpublications/52383/items/1.0348746

[41] *Id.*; *Also see:* Jurist Legal News, "Recognizing Nature's Value: The Environment Does Not Work for Free," (February 26, 2021), https://www.youtube.com/watch?v=5awJKSw0IqE.

Appendix II: California Healthy Soils Program (CA HSP)

1.1. Basic Program Information

- **Location**: California
- **Year founded**: Established in 2016 and launched in 2017 as a result of CA's 2015 Healthy Soils Program[42,43]
- **Program administrator**: California Department of Food and Agriculture (CDFA)
- **Size of program**: 646 projects[44,] covering 54,084 acres.[45]
- **Affiliates**: "CDFA has funded technical assistance providers, comprising of university cooperative extension specialists and Resource Conservation Districts (RCDs) across major agricultural counties in California, and, non-profits in expertise with agricultural management and conservation…In 2019, CDFA expanded the available expertise by developing a collaboration with the University of California Agricultural and Natural Resources, where dedicated staff resources (Community Education Specialists) have been hired to assist farmers in applying for funding and implementing their projects"[46]. For a full list of technical assistance providers see "List of CDFA-Funded Technical Assistance Providers and University of California Cooperative Extension Climate Smart Agriculture Community Education Specialists for 2020 HSP Incentives Program."[47]

1.2 General Program Details

- **Program target participants:** California farmers, ranchers and Federal and California Recognized Native American Indian Tribes. Eligible agricultural operations include row, vineyard, field and tree crops, commercial nurseries, nursery stock production, and livestock and livestock product operations. Farmers can also concurrently use funds from EQIP, but HSP funds cannot be used for activities or costs covered by other state or federal programs. University farms, research farms, and community gardens are not eligible nor are fields or crops that are not suitable based on NRCS Conservation Standards or NRCS California Practice Scenarios.[48]
- **Prerequisites for enrollment**: Must use must use the CDFA HSP Re-Plan Tool.[49] Enrollment is voluntary.[50] See below for more information.
- **Required data**: Three years of baseline data on leased or owned fields. [51]

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[42] CalCan. Healthy Soils Program. 2021. https://calclimateag.org/hsp/ Accessed: October 24, 2021.
[43] CDFA. "An Interagency Plan to Reduce Greenhouse Gases and Improve Drought Resiliency by Innovating Farm and Ranchland Practices." Healthy Soils Action Plan. September 14, 2016. https://www.cdfa.ca.gov/oefi/healthysoils/docs/ca-healthysoilsactionplan.pdf Accessed: October 24, 2021.
[44] CalCan. Healthy Soils Program. 2021. https://calclimateag.org/hsp/ Accessed: October 24, 2021.
[45] Gunasekara, Amrith. California's Healthy Soils Program: an interview with Dr. Amrith Gunasekara. Climate Group. July 31, 2020. https://www.theclimategroup.org/our-work/news/californias-healthy-soils-program-interview-dr-amrith-gunasekara. Accessed: October 24, 2021.
[46] *Id.*
[47] CDFA. List of CDFA-Funded Technical Assistance Providers and University of California Cooperative Extension Climate Smart Agriculture Community Education Specialists for 2020 HSP Incentives Program. August 27, 2021. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives-TAPWorkshops.pdf Accessed: October 24, 2021.
[48] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.
[49] *Id.*
[50] CDFA. "An Interagency Plan to Reduce Greenhouse Gases and Improve Drought Resiliency by Innovating Farm and Ranchland Practices." Healthy Soils Action Plan. September 14, 2016. https://www.cdfa.ca.gov/oefi/healthysoils/docs/ca-healthysoilsactionplan.pdf Accessed: October 24, 2021.
[51] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.

Appendix II: California Healthy Soils Program (CA HSP)

1.2 General Program Details (cont'd)

- **Length of contract**: 3 years[52]
- **Annual budget**:
  FY 2021-2022 budget: $50 million
  Grants awarded to date (2021): $41.5 million[53]
- **Funding source**: Between 2016 and 2019, HSP received $40.5 million in funding from California's Climate Investment (CCI), California's cap and trade proceeds. Through the California Drought, Water, Parks, Climate, Coastal Protection and Outdoor Access for all Act of 2018, HSP received $10 million.[54] Funding also comes from Greenhouse Gas Reduction Fund and Proposition 68. [55], "After an initial allocation of $7.5 Million, the California State Legislature appropriated to CDFA $15 Million in 2018-19 and $28 Million in 2019-20." [56]
- **Payment mechanism**: Through CDFA and CARB. Is a flat-rate payment systems based on yearly verification and invoicing.
- **Goals/expected outcome(s)**: Reduced GHG emissions at 40% below 1990 levels by 2030.[57] Healthy Soils Initiative short-term actions: establish short and long-term goals for building SOM, identify knowledge gaps, provide healthy soils guidance and long-term actions: identify financing opportunities, develop the market, provide research, education and technical assistance, increase government efficiency, ensure interagency
- **Goals/expected outcome(s) (cont'd)**: coordination.[58,59] CDFA estimates greenhouse gas reductions over 3 years to total 109,809 metric tons CO2.[60]
- **Accepted conservation practices**: Practices that may be compensated include, but are not limited to cover cropping, no-till, reduced-till, mulching, compost application, and conservation plantings. [61] For full list, see end of Appendix A. Expected lifespan for most practices is 3 years, except those with woody cover practices which is 10 years.[62]
- **Ecosystem services measured**: carbon sequestration and reduction of carbon, nitrous oxide, and methane emissions.

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[52] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf October 24, 2021.
[53] CalCan. Healthy Soils Program. 2021. https://calclimateag.org/hsp/ Accessed: October 24, 2021.
[54] State of California. "How is the Healthy Soils Program Funded?" Healthy Soils Program. 2021. https://www.cdfa.ca.gov/oefi/healthysoils/ Accessed: October 24, 2021.
[55] CalCan. Healthy Soils Program. 2021. https://calclimateag.org/hsp/ Accessed: October 24, 2021.
[56] Gunasekara, Amrith. California's Healthy Soils Program: an interview with Dr. Amrith Gunasekara. Climate Group. July 31, 2020. https://www.theclimategroup.org/our-work/news/californias-healthy-soils-program-interview-dr-amrith-gunasekara Accessed: October 24, 2021.
[57] CDFA. "An Interagency Plan to Reduce Greenhouse Gases and Improve Drought Resiliency by Innovating Farm and Ranchland Practices." Healthy Soils Action Plan. September 14, 2016. https://www.cdfa.ca.gov/oefi/healthysoils/docs/ca-healthysoilsactionplan.pdf Accessed: October 24, 2021.
[58] CDFA. "Healthy Soils Initiative." Administration/Department of Food and Agriculture Work Product. n.d. https://www.cdfa.ca.gov/EnvironmentalStewardship/pdfs/ShortTermActions.pdf Accessed: October 24, 2021.
[59] CDFA. "An Interagency Plan to Reduce Greenhouse Gases and Improve Drought Resiliency by Innovating Farm and Ranchland Practices." Healthy Soils Action Plan. September 14, 2016. https://www.cdfa.ca.gov/oefi/healthysoils/docs/ca-healthysoilsactionplan.pdf Accessed: October 24, 2021.
[60] CalCan. Healthy Soils Program. 2021. https://calclimateag.org/hsp/ Accessed 24.10.2021
[61] State of California. "How is the Healthy Soils Program Funded?" Healthy Soils Program. 2021. https://www.cdfa.ca.gov/oefi/healthysoils/ Accessed: October 24, 2021.
[62] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.

Appendix II: California Healthy Soils Program (CA HSP)

1.2 General Program Details (cont'd)

- **Method of ecosystem services measurement**:
  1. "White paper titled 'Compost Application Rates for California Croplands and Rangelands for a CDFA Healthy Soils Incentives Program', available at: https://www.cdfa.ca.gov/oefi/healthysoils/docs/CompostApplicationRate_WhitePaper.pdf
  2. California Air Resources Board (CARB) Healthy Soils Quantification Methodology (QM) available at: https://ww2.arb.ca.gov/resources/documents/cci-quantificationbenefits-and-reporting-materials.
  3. COMET-Planner Report: This report explains the scientific approaches that the quantification methodology has been utilized to estimate greenhouse gas reduction benefits for the CDFA HSP and is available at: http://bfuels.nrel.colostate.edu/health/COMET-Planner_Report_Final.pdf
  4. CDFA's Report on Whole Orchard Recycling https://www.cdfa.ca.gov/oefi/efasap/docs/WORforPublicCommentReport.pdf"[63]

1.3 Payment Details

- **Practice or performance:** Performance (based on modeling and soil samples/OM analysis)
- **Ecosystem services paid**: Improved soil health, sequestered carbon, and reduced greenhouse gas emissions.[64] Co-benefits include enhanced soil water-holding capacity, promoting bio-diversity, preventing erosion, enhancing air and water quality.[65]
  CDFA seeks public input on new practices to be eligible for the HSP. See HSP New Management Practices 2020 for a recent list of proposed eligible practices.[66]
- **Payment (cost) per unit of service**: Payment structure is clear, but this may be newly implemented in 2020.[67] See Healthy Soils Program Incentive Application guidebook for detailed payment structure for other cropland practices, orchard/vineyard, and grazing operations.[68] For example, on cropland, applying compost can be compensated up to $50/ton, converting to unfertilized perennials can range from $231.54-1,741.14/acre, depending on species, increase rotations or include perennials in rotation can range from $20.06-53.50/acre, cover cropping can range from $89.20-106.70/acre, adding a field border ranges from $130.64-1,396.19/acre depending on species, nutrient management planning that results in 15% fertilizer reduction rate by $14.72/acre, no-till or strip till is $33.82/acre, reduced till is $29.00/acre.
- **Average payment**: The 2020 maximum Healthy Soils Incentives Program grant award is $100,000.[69] See Table 1 for more information.

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[63] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.

[64] State of California. "Funding." California's Healthy Soils Initiative. 2021. https://www.cdfa.ca.gov/healthysoils/ Accessed: October 24, 2021.

[65] Gunasekara, Amrith. California's Healthy Soils Program: an interview with Dr. Amrith Gunasekara. Climate Group. July 31, 2020. https://www.theclimategroup.org/our-work/news/californias-healthy-soils-program-interview-dr-amrith-gunasekara Accessed: October 24, 2021.

[66] CDFA. "CDFA Healthy Soils Program (HSP) New Management Practices Proposals Recommendations for Public Comment." HSP New Management Practices 2020. 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/hsp_new_management_practices_cdfa_recommendations_july_2021.pdf Accessed: October 24, 2021.

[67] Lyle, Steve and Victor Hernandez. "CDFA Announces Changes for Next Round of Healthy Soils Program Grants." News Release. February 24, 2020. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ca/newsroom/releases/?cid=NRCSEPRD1549218 Accessed: October 24, 2021.

[68] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.

[69] *Id.*

Appendix II: California Healthy Soils Program (CA HSP)

2. **Program History**

"California's Healthy Soils Initiative is a collaboration of state agencies and departments, led by the California Department of Food and Agriculture, to promote the development of healthy soils. A combination of innovative farm and land management practices contribute to building adequate soil organic matter that can increase carbon sequestration and reduce overall greenhouse gas emissions."[70] The Healthy Soils Incentive Program is a part of California's Healthy Soils Initiative. The Healthy Soils Incentive Program is funded through California Department of Agriculture and Food in coordination with the California Air Resources Board.[71]

3. **Program Process**

- **Project funding:** In 2020, the California Department of Food and Agriculture appropriated $28 million to the Healthy Soil Program through the Budget Act of 2019. [72] For FY 2021-2022, the California Department of Food and Agriculture appropriated $50 million to the Healthy Soil Program through the Budget Act of 2021.[73] (Lyle, 2021)
- **Project application process:**
  Farmers must enter baseline data of management history and yield for past three years and future 3 years. [74] "Applicants proposing to include Compost Application and/or Whole Orchard Recycling practices in their projects must use the CDFA HSP Re-Plan Tool to check if the project site is eligible for the practice." Those applying to reduce GHG emissions must submit as a part of their application estimated GHG reduction and projected cost as produced by the COMET-Planner tool. [75] Project design must be submitted using the CDFA-HSP Re-Plan tool. Providing an optional Conservation Plan (created by NRCS, CCA, or other specialist) will give the application additional points.
- **Project implementation**
  "Eligible agricultural management practices can be implemented alone or in combinations, except where specified, on one APN or several APNs. Specific fields within each APN where agricultural management practice(s) will be implemented should be named by Field (Such as Field 1, Field 2, Field 3, etc.). o Each field must be outlined clearly on the APN map. All fields must have the selected agricultural management practices implemented each year for the duration of the project term. Implementations must begin prior to the end (i.e. December 31) of each project year. Multiple management practices may be included within the same APN (except for Non-Overlapping Practices), and multiple APNs within the same agricultural operation may be included in the project. Once awarded, recipients may not change the APNs included in the grant application through the duration of the project. Implementation of eligible management practices will be incentivized based on payment rates. [76] See 2020 grant application guidebook for specifics by agricultural and practice type (orchard, grazing, row, etc.).

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[70] State of California. "Funding." California's Healthy Soils Initiative. 2021. https://www.cdfa.ca.gov/healthysoils/ Accessed: October 24, 2021.
[71] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.
[72] *Id.*
[73] Lyle, Steve. "CDFA Accepting Public Comments on Healthy Soils Program Guidelines." News Release. Release #21-113. September 9, 2021. https://www.cdfa.ca.gov/egov/Press_Releases/Press_Release.asp?PRnum=21-113 Accessed: October 24, 2021.
[74] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.
[75] *Id.*
[76] *Id.*

Appendix II: California Healthy Soils Program (CA HSP)

3. **Program Process (cont'd)**
   - **Monitoring, reporting, payment process**
     Awardees must submit baseline soil samples, soil samples after each year of implementation, and annual reports. [77]. Practices are verified by CDFA environmental scientists. [78]
   - **Post-project review and evaluation**
     If project has been completed, detail of self-evaluation and project review. Awardees are expected to maintain documentation on management practices and any soil samples for three years after completion of the project as well as SOM analysis three years after project implementation/project closeout. [79]

4. **Concerns/Issues**
   Although this program supports a variety of practices, it does not compensate farmers who already have adopted the practice. Dr. Amrith Gunasekara, Science Advisor to the Secretary at the California Department of Food and Agriculture, noted issues in initiating the program included creating an easy application process, advertising the program, ensuring adequate government accountability, and building trust between operators and government. Gunasekara found that collaborating with partners was essential to engage farmers. [80]

[77] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.
[78] *Id.*
[79] *Id.*
[80] Gunasekara, Amrith. California's Healthy Soils Program: an interview with Dr. Amrith Gunasekara. Climate Group. July 31, 2020. https://www.theclimategroup.org/our-work/news/californias-healthy-soils-program-interview-dr-amrith-gunasekara Accessed: October 24, 2021.

Appendix II: California Healthy Soils Program (CA HSP)

List of all eligible practices[81]:

I. Cropland
- Alley Cropping (USDA NRCS CPS 311)
- Compost Application
  - Compost Purchased from a Certified Facility
  - On-farm Produced Compost
- Conservation Cover (USDA NRCS CPS 327)
- Conservation Crop Rotation (USDA NRCS CPS 328)
- Contour Buffer Strips (USDA NRCS CPS 332)
- Cover Crop (USDA NRCS CPS 340)
- Field Border (USDA NRCS CPS 386)
- Filter Strip (USDA NRCS CPS 393)
- Forage and Biomass Planting (USDA NRCS 512)
- Grassed Waterway (USDA NRCS CPS 412)
- Hedgerow Planting (USDA NRCS CPS 422)
- Herbaceous Wind Barrier (USDA NRCS CPS 603)
- Mulching (USDA NRCS CPS 484)
- Multi-story Cropping (USDA NRCS CPS 379)
- Nutrient Management (USDA NRCS CPS 590) (15% reduction in fertilizer application only)
- Residue and Tillage Management – No-Till (USDA NRCS CPS 329)
- Residue and Tillage Management − Reduced Till (USDA NRCS CPS 345)
- Riparian Forest Buffer (USDA NRCS CPS 391)
- Riparian Herbaceous Cover (USDA NRCS CPS 390)
- Strip Cropping (USDA NRCS CPS 585)
- Tree/Shrub Establishment (USDA NRCS CPS 612)
- Vegetative Barriers (601) (USDA NRCS CPS 601)
- Windbreak/Shelterbelt Establishment (USDA NRCS CPS 380)

II. Orchard or Vineyard
- Compost Application
  - Compost Purchased from a Certified Facility
  - On-farm Produced Compost
- Conservation Cover (USDA NRCS CPS 327)
- Cover Crop (USDA NRCS CPS 340)
- Filter Strip (USDA NRCS CPS 393)
- Hedgerow Planting (USDA NRCS CPS 422)
- Mulching (USDA NRCS CPS 484)
- Nutrient Management (USDA NRCS CPS 590) (15% reduction in fertilizer application only)
- Residue and Tillage Management – No-Till (USDA NRCS CPS 329)
- Residue and Tillage Management − Reduced Till (USDA NRCS CPS 345)
- Whole Orchard Recycling
- Windbreak/Shelterbelt Establishment (USDA NRCS CPS 380)

III. Grazing Land
- Compost Application
  - Compost Purchased from a Certified Facility
  - On-farm Produced Compost
- Hedgerow Planting (USDA NRCS CPS 422)
- Prescribed Grazing (USDA NRCS CPS 528)
- Range Planting (USDA NRCS CPS 550)
- Riparian Forest Buffer (USDA NRCS CPS 391)
- Silvopasture (USDA NRCS CPS 381)
- Tree/Shrub Establishment (USDA NRCS CPS 612)
- Windbreak/Shelterbelt Establishment (USDA NRCS CPS 380)

[81] CDFA. 2020 Healthy Soils Program Incentives Program Request for Grant Applications. February 27, 2020. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020_HSP_Incentives_RGA.pdf Accessed: October 24, 2021.

Appendix II: California Healthy Soils Program (CA HSP)

Other resources not cited:

2021 HSP list of New Management Proposals: https://www.cdfa.ca.gov/oefi/healthysoils/docs/2021/cdfa_responses_to_public_comments_sep_2021.pdf

2020 HSP list of applicants: https://www.cdfa.ca.gov/oefi/healthysoils/docs/2020-HSPIncentives-SubmittedApplications.pdf

2020 CA HSP awarded- Updated January 11, 2021 (first come, first serve): https://www.cdfa.ca.gov/OEFI/healthysoils/docs/2020_HSP_Incentives_Projects_Selected_for_Awards.pdf

2018 HSP list of applicants:https://www.cdfa.ca.gov/oefi/healthysoils/docs/2018-HSPIncentives-SubmittedApplications.pdf

2018 CA HSP awarded:https://www.cdfa.ca.gov/oefi/healthysoils/docs/2018-HSPIncentives-SelectedProjects.pdf

Appendix III. Conservation Stewardship Program

1. **Basic Program Information:**
    - **Program name:** Conservation Stewardship Program (CSP)
    - **Program location:** United States (National)[82]
    - **Year founded:** Began as the Conservation Security Program in the 2002 Farm Bill, evolved into CSP in 2008 when it first became available in all states and counties every year.[83] The program's continuation depends on reauthorization in each new farm bill—so far, it has been reauthorized in 2014 and 2018.[84]
    - **Size of program (# of farms, landowners, etc.):** 4,922 active contracts [2020][85],
    - **Acreage of program**: 6,426,631.8 acres on active contracts[86]
    - **Minimum acreage required**: No minimum[87]
    - **Program administrator:** Natural Resource Conservation Service (NRCS)[88]
    - **Targeted participants**: Agricultural and forest producers looking to increase conservation actions on their land.[89]
    - **Prerequisites for enrollment**:[90]
        - Enrolled land must be private agricultural land, agricultural Indian land, nonindustrial private forest land, farmstead, associated agricultural land or public land controlled by the applicant and part of their operation.
        - No minimum acreage requirement, but an entire operation is enrolled into the program, not specific fields.
        - "All land must be in compliance with USDA highly erodible land and wetland conservation provisions to be eligible for CSP."
        - Applicants must currently be meetings or exceeding the 'stewardship threshold'[91] for at least two priority resource concerns.
        - Applicants must have a Farm number registered with the FSA.
        - CSP is limited to farmers with less than $900,000 annual adjusted gross income.
    - **Required data sharing**: Geospatial data during application[92]
    - **Budget (overall, annual, etc.):** Between $700 million and $1 billion authorized each year for new enrollments (total funding available in 2021, for new and existing enrollments, equals $1,697,000,000).[93]
    - **Funding source/who pays:** Mandatory funding authorized through the Farm Bill.[94]
    - **Duration of program:** 5 year contract.[95]

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82 NSAC, "Farmers' Guide to the Conservation Stewardship Program; November 2020 edition," 8 (2020), https://sustainableagriculture.net/wp-content/uploads/2020/11/CSP-2020-draft3-interactive-1-1.pdf. [*hereafter* NSAC Guide]
83 *Id.* at 5
84 *Id.*
85 NRCS, "NRCS Conservation Programs: Conservation Stewardship Program," (updated 2-24-21; accessed 10-29-21), https://www.nrcs.usda.gov/Internet/NRCS_RCA/reports/fb08_cp_cstp.html. [*hereafter* NRCS]
86 *Id.*
87 USDA, "Conservation Stewardship Program: Is CSP Right for Me?" 2 (July 2021).
88 NSAC, "Conservation Stewardship Program," (updated April 2019; access 10-29-21), https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/conservation-stewardship-program/. [*hereafter* NSAC CSP]
89 *see* NSAC Guide at 8.
90 *Id.* at 8-9.
91 *Id.* at 19: "*Stewardship thresholds are science-based metrics that establish a sustainable use level for a particular natural resource. Meeting or exceeding the threshold means that you are satisfactorily addressing the resource concern*."
92 *Id.* at 13.
93 *see* NSAC CSP
94 Congressional Research Service, "FY2021 Appropriations for Agricultural Conservation," 7 (3/19/2021), https://www.everycrsreport.com/reports/R46728.html.
95 *see* NSAC Guide at 6.

Appendix III. Conservation Stewardship Program

1. **Basic Program Information (cont'd):**
   - **Goal/expected outcome(s):** "CSP provides financial assistance for conservation activities that improve soil health, sequester carbon, reduce greenhouse gas emissions, slow erosion, improve water and air quality, increase biodiversity, support wildlife and pollinator habitat, and conserve water and energy."[96]
   - **Specific conservation practices mentioned/measured**: Wide-ranging and dependent on contract. *See* "CSP FY 2021 Enhancements and Bundles" *for more information.*[97]
   - **Ecosystem services measured:** Varies by contract. *See* "CSP FY 2021 Enhancements and Bundles" *for more information.*[98]
   - **Method of ecosystem services measurement**: Reporting/ verification that practices were implemented.[99]
   - **Practice or performance**: Practice[100]
   - **What is paid for**: verified implementation of practices as specified by the conservation plan.[101]
   - **Payment (cost) per unit of service**: Payments vary by state and are allocated on a per acre basis; NRCS pays a minimum $1,500 per year and a maximum of $40,000 per year ($200,000 over a 5 year contract).[102]
   - **Payment mechanism**: Payment amount = (Number of acres enrolled x per acre payment rate by land use) + (Number of resource concerns met x Payment per resource concern) + (Number of acres treated x Enhancement payment rate)[103]
   - **Average payment**: National: 1,319 acres, $15,477; Northeast: 767 acres, $8,556[104]

2. **History/Brief Overview**

CSP's main objective is to provide technical and financial assistance to reward farmers and ranchers for ongoing conservation efforts and incentive additional conservation enhancements.[105]

CSP began in the 2002 Farm Bill as the Conservation Security Program and changed to its current name when it was reauthorized in the 2008 Bill.[106] The program underwent significant changes in the 2018 Bill when it transitioned from and acreage-based program to a payment-based program, meaning that the USDA was capped on the amount spent rather than the acreage enrolled.[107] Additionally, participants were no longer guaranteed re-enrollment after the end of a 5 year contract.[108] The 2018 Bill also cut the program's funding to instead bolster other programs, and this change made CSP more competitive.[109]

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[96] *Id.* at 4.
[97] USDA, "CSP FY 2021 Enhancements and Bundles," (accessed 10-21-29), https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/csp/?cid=nrcseprd1708431.
[98] *Id.*
[99] *see* NSAC Guide at 38-39.
[100] USDA, "CSP—Learn More," (accessed 10-29-21), https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/financial/csp/?cid=nrcseprd1288524.
[101] *see* NSAC Guide 14-15.
[102] USDA, "CSP Payments," (accessed 10-29-21), https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/financial/csp/?cid=nrcseprd1297344.
[103] *see* NSAC Guide 30-31.
[104] *Id.* at 49
[105] *Id.* at 6.
[106] National Association of Conservation Districts, "2018 Farm Bill Breakdown: Conservation Stewardship Program," (01/15/2019; accessed 11/22/2021), https://www.nacdnet.org/2019/01/15/2018-farm-bill-breakdown-conservation-stewardship-program/.
[107] *Id.*
[108] *Id.*
[109] *Id.*

3. Program Process

Details of application, prerequisites, baseline assessments, objectives, payment calculation, etc.

i. *Pre-implementation of project/funding*[110]

Participants apply through their local NRCS office. The participant's application is then ranked through the Conservation Application Ranking Tool (CART), which selects farms based current resource conditions, which are given point values determined by information gathered through geospatial analysis data of soil and landscape features, current practices reported by the farmer, and on-site observation by a local conservationist.

Each condition's point score is compared with its stewardship threshold, following which the participant identifies the best conservation practices to implement. The combined information ranks the farm and compares it to others and determines how much funding the farmer will receive if accepted.

ii. *Details of actions by participants/funder for monitoring, reporting, & payment process.*[111]

If application is approved, an NRCS representative works with the farmer to develop a conservation plan. The farmer is then responsible for implementing the various enhancements detailed in the plan, and for reporting on those implementations each year.

Reporting requirements are different for each conservation activity. Below is a hypothetical example of a contract process for a soil health rotation:

- The farmer provides NRCS with current and planned crop rotations
- While implementing the conservation plan, the farmer notifies NRCS of any changes and keeps records of management, including dated pictures at least once every three months to record progress.
- The farmer reports review pictures and records to NRCS annually.
- Payments are delivered each October, contingent on successful reporting.

4. Concerns/Issues

Unlike a proper PES program, which would pay for the value of services produced, CSP operates through an 'income-foregone framework' that focuses payments on compensating farmers for profits lost for pursuing conservation practices.[112] Limited funding makes the program highly competitive and limits the extent of its impact.[113] Furthermore, the program's ranking system selects for the greatest return on investment which is often received from farms with more degraded land and ranks farms with fewer resource concerns lower.[114]

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[110] *see* NSAC Guide at 12-13.
[111] *Id.* at 38.
[112] Gordon Merrick, "A Lens for Analysis of Payment for Ecosystem Services Systems: Transitioning the Working Lands Economic Sector from Extractive Industry to Regenerative System," *Land* 646 (2021), https://doi.org/10.3390/land10060637.
[113] Lindsay Campbell, "Conservation Stewardship Program is Falling Short, Say Critics," Modern Farmer, (March 15, 2020), https://modernfarmer.com/2020/03/conservation-stewardship-program-is-falling-short-say-critics/.
[114] *Id.*

Appendix IV: Carbon Forest Project (FCP)

1.1 Basic Program Information

- **Location**: Seven Vermont towns (Bakersfield, Belvidere, Enosburgh, Fletcher, Montgomery, Richford, and Waterville). CHC encompasses nearly 170,000 acres.[115]
- **Year founded**: Founded in 2009. 2008 (year community had first meeting to identify important forest areas. [116] CHC became incorporated in 2011.[117] In 2013, the Cold Hollow to Canada Regional Conservation Partnership volunteer group was established as a non-profit.[118] In 2019, the Vermont Forest Carbon Company (VFC), a third party subsidiary of VLT was formed.[119]
- **Program Administrator**: Cold Hollow to Canada and The Vermont Land Trust (VLT) are the lead administrating organizations. The FCP may also be referred toa s the Carbon Aggregation Project. CHC acts as convener agent for FCP. Third party measures and verifies results.[120] The Carbon Aggregation Project pools the forested acres of multiple landowners together to put on the carbon market.[121] "VFC purchases carbon credits from individual forestland owners, pools and sells the credits as a single project, and then compensates the forestland owners generating the credits. In this model, VLT took some of the credit share to cover the cost of risk. Landowners would therefore receive a lower price per credit in exchange for the lower risk."[122] This program is helpful because the economics to set-up carbon offsets works well for parcels of 5,000 acres, but the burden of market entry may be too great for more typical Vermont parcels of 500 acres or less.[123]
- **Program mission statement**: Our mission is to maintain ecosystem integrity, biological diversity, and forest resiliency throughout the Cold Hollow to Canada region, with a focus on community-led stewardship and the conservation of our working landscape in the face of a changing climate.[124]
- **Partners**: The Vermont Land Trust to help coordinate easements. Intentions to increase collaboration with, the Forest Legacy Program, and Northeast Wilderness Trust in order to leverage funds and hold easements for the permanent protection of forestland.[125]CHC partners with local communities to develop forest management plans and in some cases helps set-up conservation funds (like in Enosburgh and Montgomery) to leverage with CHC funds for

[115] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[116] *Id.*
[117] opencorporates. Cold Hollow to Canada Incorporated. 2021. https://opencorporates.com/companies/us_vt/0091728 Accessed 30.10.2021
[118] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.
[119] *Id.*
[120] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30,2021.
[121] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[122] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.
[123] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[124] *Id.*
[125] *Id.*

Appendix IV: Carbon Forest Project (FCP)

1.1 Basic Program Information (cont'd)

- **Partners (cont'd)**:
  bigger impact.[126] CHC partners with Vermont Fish & Wildlife Department for the WildCam project where seven game cameras are set up to film, track, and monitor wildlife as wildlife is an indicator of the health of the forest.[127] For full list, see end of Appendix B.
- **Size of program**: There are 8,625 acres enrolled across 12 parcels and 10 landowners.[128] Current FCP is a pilot and is no longer accepting applications.[129]

1.2 General Program Details

- **Program target participants**: Forest owners within the seven towns for CHC and pilot FCP.
- **Prerequisites for enrollment**: Participants must meet American Carbon Registry standards [130] For the Conservation Fund (up to $10,000 to landowners for conservation transaction costs) requires a minimum of 60% forest cover on a minimum of 50 acres in one of the seven towns in a priority area (plus more).[131] The SIG Carbon group "will take on all risk and cover all upfront development costs. A monitoring fund will cover costs through the lifetime of the project, eliminating surprise expenses."[132] "Current use tax policies do not preclude carbon offset eligibility." [133] Those enrolled in VT Current Use, Forest Legacy, EQIP, Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC), or American Tree Farm are eligible and conservation easement on forestland should not restrict eligibility.[134] Minimum acreage required for feasibility study is 500 acres, 450 of which must be forested [135]
- **Required data**: It is not clear if there is more than granting land access for forest for inventory and assessments.

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[126] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[127] *Id.*
[128] CHC. "Forest Carbon Aggregation." Programs. 2021. https://www.coldhollowtocanada.org/programs/carbon Accessed: October 30,2021.
[129] *Id.*
[130] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30,2021.
[131] CHC. "Conservation Fund." Programs. 2021. https://www.coldhollowtocanada.org/programs/conservation-fund Accessed: October 30,2021.
[132] SIG Carbon. "SIG Carbon Aggregation Program." Aggregation. 2021.https://www.sigcarbon.com/scap Accessed: October 30,2021.
[133] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.
[134] Kosiba, AM. "Forest Carbon Markets for Vermont Landowners." Vermont Department of Forests, Parks and Recreation. 2021. https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Climate_Change/Files/ForestCarbonOffsetsForVermontLandowners_Mar2021.pdf Accessed: October 30,2021.
[135] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.

Appendix IV: Carbon Forest Project (FCP)

1.2 General Program Details (cont'd)

- **Length of contract**: Per American Carbon Registry standards, the duration is 40 years for Carbon Aggregation Project.[136] Price range in the Carbon Aggregation Project is projected for the first 10 years.[137] The agreement is connected with the land and is "binding on any transfer of ownership of the property."[138]
- **Budget**: The FCP is a pilot project and it looks like funds were awarded amounting to $795,000 to implement the program.[139] "CHC project is funded by grant money that created a starting pool of resources and will be replenished by VLT's share of the credit purchases, which will in turn be used to develop other projects. This differs from other carbon offset projects that are funded by the sale of credits to either a landowner or to a private carbon development company, depending on which one assumes the transaction costs, In other words, instead of landowners or a private company paying for the transaction costs associated with developing a forest carbon project, VLT, a land trust, maintains a revolving fund that covers transaction costs in exchange for credits that replenish the fund and allow it to finance additional projects."[140]
- **Funding source**: CHC which supports FCP is funded by a variety of organizations: Farnsworth Fund, The High Meadows Fund, Jessie B. Cox Charitable Trust, Lintilhac Foundation, Natural Resources Conservation Service, The Nature Conservancy, US Forest Service, Vermont Agency of Natural Resources, Vermont Land Trust, Vermont Natural Resource Council.[141] Donations are also accepted e.g. Switchback donated 5% of taproom sales on March 5, 2020)[142]
- **Payment mechanism**: Carbon credit market. Amazon has committed $10 million to restore and conserve four million acres of forest in the Appalachians in partnership with The Nature Conservancy.[143,144]. Of the $10 million, $2.5 million worth of carbon credits through the Carbon Aggregation Project.[145] Another purchaser is Gratitude Railroad (CIG Carbon, 2021).

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[136] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30,2021.

[137] SIG Carbon. "LandTrusts Vermont Land Trust Aggregation Project." Projects. 2021.https://www.sigcarbon.com/case-study/cold-hollow-to-canada-carbon-cooperative-vernmont-land-trustAccessed 30.10.2021.

[138] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[139] CHC. "Our Vision."2018. http://www.wildlandsandwoodlands.org/sites/default/files/B4.%20Hancock%20%20RCPNG%202018.pdf Accessed 31.10.2021.

[140] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[141] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed 30.10.2021

[142] Switchback, "Switchback Gives Back to Cold Hollow to Canada." Events. 2020. https://www.switchbackvt.com/calendar/2020/3/5/switchback-gives-back-to-cold-hollow-to-canada Accessed 30.10.2021.

[143] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30,2021.

[144] Amazon. "As Part of Its Plan to be Net Zero Carbon by 2040, Amazon Commits $10 Million to Restore and Conserve 4 Million Acres of Forest in the Appalachians and other U.S. Regions in Partnership with The Nature Conservancy." Press Release. Amazon Press Center. April 21, 2020. https://press.aboutamazon.com/news-releases/news-release-details/part-its-plan-be-net-zero-carbon-2040-amazon-commits-10-million Accessed: October 30,2021.

[145] CHC. "Forest Carbon Aggregation." Programs. 2021. https://www.coldhollowtocanada.org/programs/carbon Accessed: October 30,2021.

Appendix IV: Carbon Forest Project (FCP)

1.2 General Program Details (cont'd)

- **Payment mechanism (cont'd)**:
  Vermont Gas System (VGS) announced its partnership with Vermont Land Trust to purchase carbon credits through the Forest Carbon Cooperative.[146]
  It is not clear if this is a part of CHC Carbon Aggregation Project, but VGS lists CHC as one of the contributing partners and the Forest Carbon Cooperative has similar farm and acres numbers as the Carbon Aggregation Project.[147,148] Members of VLT purchased credits to offset personal emissions.[149]
- **Goal/expected outcome**(s): "Vision: A resilient and connected ecosystem across the entire Northern Forest that is supported through permanent protection, sustainable stewardship, and engaged local communities.[150] Conserve another 23,000 acre by 2030 (double the amount conserved when CHC started).[151]
  - "Increased carbon sequestration by the acres of forest enrolled in such efforts;
  - Income for landowners over 20 years to pay for enhanced forest management practices;
  - Healthier forests, cleaner water, and reduced damage from future floods;
  - A greater diversity of plants and animals, and healthier wildlife habitat;
  - Continued timber harvests and maple sugaring;
  - Potential reduction of summer heat island effects in the nearby towns and cities; and long-term protection of the Northern Forest, and the more general environmental and economic values it provides."[152]

  Net revenue of the Forest Carbon Project is expected to reach $3.5 million over 10 years.[153]
- **Accepted conservation practices**: Woodlots Program conducts a forest management climate change analysis and an interior songbird habitat assessment.[154] The FCP helps landowners sell carbon offset credits.[155] To sequester carbon, landowners can engage in a number of practices, reduced timber harvest, allowing trees to grow older, extended rotations restoring wetlands, etc.[156]

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[146] Johnson, Corey. "VGS Announces Partnership with Vermont Land Trust to Offset Vehicle Emissions and Support Sustainable Forest Management." General. April 22, 2021. https://www.vermontgas.com/vgs-announces-partnership-with-vermont-land-trust-to-offset-vehicle-emissions-and-support-sustainable-forest-management/ Accessed: October 30,2021.
[147] *Id.*
[148] Vermont Land Trust. "Forests that Reduce Carbon Pollution." 2021. https://vlt.org/forestcarbon Accessed: October 30,2021.
[149] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.
[150] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[151] *Id.*
[152] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.
[153] *Id.*
[154] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30,2021.
[155] *Id.*
[156] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30,2021.

Appendix IV: Carbon Forest Project (FCP)

1.2 General Program Details (cont'd)

- **Ecosystem services measured**: Carbon sequestration, plant and animal diversity, plant structure diversity.[157]
- **Method of ecosystem services measurement**: Verification methods not provided in detail. It appears SIG or other group conducts inventory and provides management plans to meet management and carbon sequestration goals.

1.3 Payment Details

- **Practice or performance**: Performance (based on inventory, verification, and modeling).
- **Ecosystem services paid**: Carbon sequestration.[158]
- **Baseline or threshold**: Both. The initial inventory is compared to a regional average. Payments for the length of the contract are based on the initial inventory baseline and the regional average threshold. If the landowners sequester more carbon above the initial inventory baseline they are compensated for that additionality.[159]
- **Average Payment**: Landowners can expect to receive $25-47 per acre per year.[160] Carbon payment based on market prices. For the Forest Carbon Cooperative, and average of $282 per acre will be paid to landowners, in addition to income from timber and sugaring.[161] This may be over the life of the 40-year contract which would be an average payment of $7.05/acre/year.
- **Other payments to producers**: CHC can eliminate or minimize the costs of donating an easement. These costs can range from $11,000-15,000 for legal fees and baseline documentation.[162] In some cases, CHC can purchase easements at bargain sale prices.[163]

2. Program History

Vermont forests contribute $57.3 million dollars and 23,500 jobs through logging (and logging related enterprises), recreation, and sugaring.[164] More than 2/3 of Vermont forests are privately owned. [165] Only 20% of Vermont forests are conserved.[166] Vermont is losing forest cover for the first time since the mid 1800's. [167] CHC helps facilitate landowner entry into global carbon markets through the nation's first aggregated carbon offset project.[168] In 2017, VLT commissioned a Vermont forest carbon program

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[157] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30, 2021.
[158] *Id.*
[159] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30, 2021.
[160] SIG Carbon. "LandTrusts Vermont Land Trust Aggregation Project." Projects. 2021.https://www.sigcarbon.com/case-study/cold-hollow-to-canada-carbon-cooperative-vernmont-land-trust Accessed: October 30,2021.
[161] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 30, 2021.
[162] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30, 2021.
[163] *Id.*
[164] *Id.*
[165] *Id.*
[166] *Id.*
[167] *Id.*
[168] *Id.*

Appendix IV: Carbon Forest Project (FCP)

2. **Program History (cont'd)**

feasibility study from UVM's Carbon Dynamic's Lab.[169] In 2017, CHC received a $640,000 award from NRCS for forest management. [170] The goal of this award was to expand enrolled acres from 2,000 to 8,000 and increase the number of land owners from 10 to 50, and increase number of town from Enosburg to Montgomery and Richford.[171] CHC has also received $105,000 from the Conservation Fund and $50,000 from LSR.[172] In 2018, Vermont Land Trust received funding from Meadows Fund and the Vermont Housing and Conservation Board to conduct a study on the feasibility of a carbon credit market Vermont landowners could participate in.[173]

3. **Program Process**

- **Project application process**:
  The Woodlots Program begins with CHC connecting landowners with contiguous or near-contiguous forested properties to coordinate management activities at a landscape scale.[174] This is a peer-to-peer model. [175]
  For the Forest Carbon Company, two contracts are created, one with the landowners and VFC and the landowners and another one amongst the landowners.[176]
- **Project implementation**
  Identify willing landowners, in the case of the Carbon Aggregation project, this was confined to landowners working with CHC.[177]. Then, conduct feasibility assessment, followed by two years of outreach to landowners.[178] A guide was developed "…on techniques for managing carbon stocks that was not prescriptive but allowed landowners to understand the general bounds of what they could do for project eligibility."[179] Education was not only targeted at landowners, but also County Foresters, "County foresters are crucial because they can facilitate folding carbon projects into the state's Current Use Value Appraisal program."[180] "VFC has been structured to support all stages of forest carbon program development, from providing upfront financing to forestland

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[169] White, Abby. "A Local Solution with a Global Impact: Carbon offsets protect woodland and rural livelihoods." News and Stories. Vermont Land Trust. 2021. https://vlt.org/forests-wildlife-nature/local-solution-global-impact-forest-carbon Accessed: October 31, 2021.
[170] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30, 2021.
[171] Overstreet, Amy and Bridgett Butler. "USDA to Invest $640,000 in Vermont's "Cold Hollow to Canada" Conservation Partnership to Enhance Private Forest Management." News Release. Vermont NRCS. https://www.coldhollowtocanada.org/press Accessed: October 30, 2021.
[172] CHC. "Our Vision."2018. http://www.wildlandsandwoodlands.org/sites/default/files/B4.%20Hancock%20%20RCPNG%202018.pdf Accessed: October 30, 2021.
[173] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30, 2021.
[174] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30, 2021.
[175] *Id.*
[176] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 31, 2021.
[177] *Id.*
[178] *Id.*
[179] *Id.*
[180] *Id.*

Appendix IV: Carbon Forest Project (FCP)

3. **<u>Program Process (cont'd)</u>**

- **Project implementation (cont'd)**
  owners, to reviewing forest management plans, to supporting project development, to marketing and selling credits."[181]
- **Monitoring, reporting, payment process**
  For the Carbon Aggregation Project, participants must manage their forests to maintain and increase carbon stock.[182] "The number of credits is calculated by experienced forestry experts who use field-based measurements and other sources to estimate the amount of carbon that can be sequestered by a specific forest landholding in excess of the established baseline. For both the compliance and voluntary markets, carbon credits are generated following established protocols and listed in registries; the Vermont Forest Carbon Company has used the American Carbon Registry (ACR).[183] Currently the project is in its initial implementation stages. "Forestland owner agreements were signed in Spring 2020, and while credits will not be formalized for release until Winter 2021, verification has been completed and the project has commitments for credit purchase from multiple buyers…"[184] For the FCP, SIG Carbon provides framework for cost-sharing and legal aggregation, provides forest yield growth modeling, carbon quantification services, carbon storage potential analysis, and project management (inventory design, quality assurance, contracting, project documentation, and on-site verification process).[185]
- **Post-project review and evaluation**
  The CHC pilot project was determined a success, "This proof-of-concept project has demonstrated that aggregated carbon arrangements can, in an economic and efficient manner, connect forestland owners to carbon offset markets in areas where smaller, private forestland holdings predominate. It has also demonstrated that land trusts and their special purpose subsidiaries can be appropriate homes for aggregated carbon offset projects."[186]

  Building trust among landowners and organizations involved takes time.[187] Although the 40-year contract is less than the 100 year California Air Resources Board (CARB) contracts, the length of time is a barrier.[188] The contracts are with landowners who are already on the path to conserving.[189] Help entering different landowners is one of the next steps. The Land Trust

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[181] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[182] CHC. "Forest Carbon Aggregation." Programs. 2021. https://www.coldhollowtocanada.org/programs/carbon Accessed 30.10.2021.

[183] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[184] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[185] SIG Carbon. "LandTrusts Vermont Land Trust Aggregation Project." Projects. 2021.https://www.sigcarbon.com/case-study/cold-hollow-to-canada-carbon-cooperative-vernmont-land-trustAccessed 30.10.2021.

[186] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021. https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

[187] *Id.*

[188] *Id.*

[189] *Id.*

Appendix IV: Carbon Forest Project (FCP)

3. **<u>Program Process (cont'd)</u>**
   - **Post-project review and evaluation (cont'd)**
     Alliance, Finite Carbon, and The Climate Trust have partnered in a new 5- year pilot project to "pool Land trust resources for the voluntary carbon market. Under this partnership, Finite Carbon will support land trusts with their forestlands and The Climate Trust will support purchasing no-till grassland easements for the carbon market."[190] Lessons learned from the Forest Carbon project will be used for the Wild Carbon Initiative project which will encompass nearly 10,000 acres in the Northeast.[191]

4. **Concerns/Issues**
   Methods of enrollment and verification are not easily publicly accessible. This may be because it is a pilot project. Program goes by multiple names: Carbon Aggregation Project (CHC) and Forest Carbon Project (VLT). It is unclear if program pays only for additionality, i.e. "maintain and increase" language, not maintain or increase. However, in the CHC case study, credits are determined against the baseline of the current inventory.[192] The carbon credits are sold against a baseline (Patch, personal communication). The pilot project was conducted with participants whose existing management plans closely aligned with practices that manage forests for carbon sequestration.[193] New markets are developing which may preclude the necessity of large parcels for a landowner to engage in the carbon market (e.g. the TNC's Family Forest Carbon Program and Finite's Core Carbon).[194] The proposed federal legislation, Rural Market's Act would provide funding for a part of the proposed Growing Climate Solutions Act that would, "USDA certification for carbon experts, developers, and third-party verifiers and an online marketplace for buyers and sellers."[195] See Kosiba (2021) for table of forest carbon developers, programs, minimum acreage, and contract length.[196]

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[190] *Id.*
[191] *Id.*
[192] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021.
https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed: October 31, 2021.
[193] *Id.*
[194] Kosiba, AM. "Forest Carbon Markets for Vermont Landowners." Vermont Department of Forests, Parks and Recreation. 2021.
https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Climate_Change/Files/ForestCarbonOffsetsForVermontLandowners_Mar2021.pdf Accessed: January 11, 2021.
[195] *Id.*
[196] I*d.*

Appendix IV: Carbon Forest Project (FCP)

List of partners:

- 2 Countries, 1 Forest
- Audubon Vermont
- The Nature Conservancy
- The Staying Connected Initiative
- The Trust for Public Land
- University of Vermont
- Vermont Department of Forests, Parks, & Recreation
- Vermont Fish & Wildlife Department
- Vermont Land Trust
- Vermont Natural Resource Council
- Wildlands Network[197]
- List of Additional Collaborators:
- Appalachian Corridor Appalachien
- Champlain Adirondack Biosphere Network
- Keeping Track
- Missisquoi River Basin Association
- Northeast Wilderness Trust
- Northern Forest Canoe Trail
- Ruiter Valley Land Trust
- Vermont Wild and Scenic Rivers[198]
- The Carbon Aggregation Project was made possible through collaboration with:
- Vermont Housing and Conservation Board
- Land Trust Alliance
- Cotyledon Fund
- High Meadows Fund[199]
- Woodlots Program is fund in part through a grant awarded by:
  Northeastern Area State and Private Forestry, U.S. Forest Service and by the High Meadows Fund.[200]
- Forest Carbon Project (VLT, offshoot of Carbon Aggregation Project)
- Vermont Land Trust
- University of Vermont
- Spatial Informatics Group (SIG) (carbon quantification and verification)
- Green Timber conducted inventory assessment
- Cold Hollow to Canada Regional Conservation Partnership
- The Nature Conservancy (farmer-market connector and funding provider)
- Through a Natural Climate Solutions Accelerator Grand funded by the Duke Foundation
- High Meadows Fund (funding)
- Vermont Housing and Conservation Board (funding)
- Lyme Timber Company (financial guidance)
- Finite Carbon (financial guidance) [201]

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[197] CHC. 2021-2025 Strategic Plan. 2021 https://www.coldhollowtocanada.org/about/strategic-plan#c302 Accessed: October 30, 2021.

[198] *Id.*

[199] Hancock, Charlie. "Forest Carbon: A Natural Climate Solution and Tool for Advancing the Pace of Conservation." News and Events. Cold Hollow to Canada. July 6, 2020. https://www.coldhollowtocanada.org/what/news/article/forest-carbon-a-natural-climate-solution-and-tool-for-advancing-the-pace-of-conservation Accessed: October 30, 2021.

[200] CHC. "Woodlots Program." Programs. 2021. https://www.coldhollowtocanada.org/programs/woodlots Accessed: October 30, 2021.

[201] Macleod, Kavita. "Cold Hollow Carbon: A Vermont Forest Carbon Cooperative for Climate Change Mitigation." Case Profile Series on Land Trusts as Climate Change Solution Providers. January 2021.

Appendix IV: Carbon Forest Project (FCP)

For further reading:
Green Timber- conducts forest inventory, creates management plans, offers third party verification services. https://greentimberforestry.com/

UMassAmherst and UVM Forest Carbon: An essential natural solution for climate change. Provides overview of forest carbon cycle as it relates to forest age and provides information on different forest management strategies. https://masswoods.org/sites/masswoods.org/files/Forest-Carbon-web_1.pdf

https://www.coldhollowtocanada.org/fileadmin/files/Case_Profile_Cold_Hollow_Carbon_VT_03_24_21_.pdf Accessed 31.10.2021

Appendix V: Glastir

1. Basic Program Information

- **Program name**: Glastir (Glastir Commons; Glastir Woodland Creation; Glastir Woodland Regeneration). The Welsh Government performed the Glastir Monitoring and Evaluation Programme from 2013 through 2016 to evaluate the environmental effects of the Glastir Programme. [202] Much of the information here dates from that evaluation. Another survey was scheduled for 2021 and remains forthcoming.
- **Program location**: Wales[203]
- **Year founded**: 2009; Glastir replaced all existing agri-environment schemes in 2013.[204]
- **Size of program (# of farms, landowners, etc.):** "There are currently 4,600 participants in the Entry level scheme, including 1,400 in the Advanced level and 500 in the Decoupled Advanced, managing 37% of the total utilised agricultural area in Wales." [2017 information][205]
- **Acreage of program**: Over 1.3 hectares (3,212,369.96 acres)[206]
- **Minimum acreage required**: 3 hectares (7.4 acres)[207]
- **Program administrator**: Welsh Assembly Government (WAG)[208]
- **Targeted participants**: Owners of Agricultural land in Wales.[209]
- **Prerequisites for enrollment**: Farms must fulfil the Whole Farm Code and meet the points threshold (must reach 28 points per hectare of eligible land).[210]

  Requirements for the Whole Farm Code
  Farms must meet several parameters, including 1) complying with Good Agricultural Environmental Conditions, 2) not extracting natural mineral resources or burn vegetation on rocky areas, 3) maintaining field records of amendment application, 4) not cultivating within 2 meters of watercourse or wetland, 5) not amending on waterlogged or frozen soil, 6) not storing manure and farm wastes on a flood risk area or high-risk slope, 7) complying with certain restrictions for cultivating maize, and 8) maintaining appropriate buffer strips (minimum 2 meters) along high risk slopes and water courses.[211] *For a full list of requirements please refer to source.*[212]

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[202] Centre for Ecology and Hydrology, "Glastir Monitoring & Evaluation Programme: Final Report," (July 2017). [*hereafter* GMEP Final Report]
[203] Llywodraeth Cynulliad Cymru, "Glastir: New Sustainable Land Management Scheme for Wales," *The European Agricultural Fund for Rural Development: Europe Investing in Rural Areas*, (2010). [*hereafter* SLM Scheme]
[204] *see* GMEP Final Report at 4.
[205] *Id.*
[206] Strut & Parker, "Future of Farm Support in Wales," (9/30/21; accessed 10/21/21), https://rural.struttandparker.com/article/future-of-farm-support-in-wales/.
[207] *see* SLM Scheme at 6.
[208] Sophie Wyne-Jones, "Connecting payments for ecosystem services and agri-environment regulations: An analysis of the Welsh Glastir Scheme," *Journal of Rural Studies*, 77 (2013), http://dx.doi.org/10.1016/j.jrurstud.2013.01.004. [*hereafter* Wyne-Jones]
[209] Welsh Government, "Glastir Entry Book 1: General Guidance 2015,"5 (2015), https://gov.wales/sites/default/files/publications/2018-01/glastir-entry-2015-rules-booklet-1.pdf. [*hereafter* Entry Book 1]
[210] *see* SLM Scheme at 4.
[211] *Id.* at 7-9.
[212] *Id.*

Appendix V: Glastir

1. **Basic Program Information (cont'd)**
   - **Prerequisites for enrollment (cont'd)**:
     Farmers who hold Common Land Rights and have joined together to establish a Grazing Association are eligible for the Common Land element.[213] Other farms will apply under the All-Wales element.[214] This summary will focus on the All-Wales Element.

     Registering for the All-Wales Element
     Participants must 1) register an interest in joining the scheme, 2) register all of their land with the Welsh Assembly Government's Land Parcel Identification System, 3) mush have full management responsibility and control over the land, either as owner or as the holder of a 5 year tenancy lease, 4) be the only claimant for the land, 5) must have a minimum 3 hectares of eligible land, 5) meet the minimum points threshold, and 6) avoid causing environmental damage of a kind that would contravene the Glastir contract conditions before entering in a contract.[215]

     Participants can enter a Targeted element, which addresses the WG's six areas of concern: soil carbon management, water quality, water quantity management, biodiversity, historic environment, and improving access.

     Registering for the Targeted Element
     1) Land must already be under contract for the All-Wales Element, and 2) all land proposed must be assessed against target maps to assess relevance to the objectives above.[216]

   - **Required data sharing**: All participants must register all of their land with the Welsh Assembly Government's Land Parcel Identification System.[217] Land for participants of the Targeted Element must be assessed against target maps to assess relevance to the objectives above.[218] Participants must also allow for regular inspections throughout the year.[219]
   - **Budget (overall, annual, etc.):** "total direct payments made to farms through Glastir were £37 million in 2015 (and provisional sum of £40 million in 2016)" [2017 information].[220]

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213 *Id*. at 3.
214 *Id.*
215 *Id.* at 5.
216 *Id.*; *See also*: Mark Reed, Andrew Moxey, Katrin Prager, Nick Hanley, James Skates, Chris Evans, Klaus Glenk, Ken Thomson, "Improving the link between payments and the provision of ecosystem services in agri-environment schemes in UK peatlands," Centre for Ecology & Hydrology, 1 (2014), http://nora.nerc.ac.uk/id/eprint/508943/1/N508943PP.pdf. [*hereafter* Reed et al.]
"*Spatial targeting of intervention measures is one of the more innovative aspects of Glastir. The scheme's Targeted Element utilises environmental data to build a simple process based model, which allows an applicant's land holding to be assed and scored against a range of priority objectives. Priority layers (maps) for a wide range of environmental objectives have been developed in conjunction with stakeholders. Layers include species, habitats, designations, soil (including peatlands), water quality and quantity access and historic environment. In addition to scoring an applicant's land holding, the simple process based model also identifies the range of options and measures most appropriate in order to attain the specific environmental benefits which the land holding offers. Contract managers further interrogate environmental data and enter into a negotiation phase with the landowner so as to agree the most equitable options. Entry into the targeted element is determined by passing a score threshold. Options include capital works and management measures, payments are in line with the regulatory framework based on cost of capital works and also opportunity cost of management measures, income forgone*."
217 *Id.*
218 *Id.*
219 *see* Entry Book 1 at 25.
220 *see* GMEP Final Report at 11.

Appendix V: Glastir

1. **Basic Program Information (cont'd)**
   - **Funding source/who pays**: Glastir is funded by Axis 2 (Improving the Environment and the Countryside) of the Welsh Government's Rural Development Programme 2014-20.[221]
   - **Duration of program**: Ongoing, but will end in 2024/2025 when Glastir will be replaced by a more comprehensive Wales Sustainable Farming Scheme.[222]
   - **Goal/expected outcome(s)**: While "[the] management specifications do relate to particular 'ecosystem' outputs, they are not intended to provide quantifiable outputs of goods and services, in terms of specific amounts of carbon or water for example. Instead, scheme agreements are based upon the management of on-farm features and habitats, in a specified manner, to maintain or promote conditions associated with particular ecosystem outputs."[223]
   - **Specific conservation practices mentioned/measured**:
     Example Management options: 1) Hedgerow management, 2) creating streamside corridors to exclude stock 3.5 meters from edge, 3) restore or create an orchard, 4) commit to slurry injections, 5) graze permanent pasture with minimal inputs, 6) manage existing habitats.[224]
   - **Ecosystem services measured**: Biodiversity, Soil, Water, Greenhouse gases, Woodlands, Access and Recreation.[225]
   - **Method of ecosystem services measurement**: Practices are verified through on-farm inspections.[226]
   - **Practice or performance**: Practice[227]
   - **What is paid for**: Implementing practices determined through application/conservation planning.[228]
   - **Payment (cost) per unit of service**: Flat rate based on land area—£35 per hectare (US$19.49 per acre) [data from 2012].[229] Farmers also receive per hectare payments under the Whole Farm Code, and those managing up to 20.00 hectares receive £15.00 per hectare, between 20.01 and 50.00 hectares receive £8.00 per hectare, between 50.01 and 100.00 hectares receive £2.75, and above 100.00 hectares there is no additional payment.[230]
   - **Payment mechanism**: The program used to operate within—and was somewhat limited by—the European Union's framework of Common Agriculture Policy (CAP) payments.[231] Conditions for transferring payments to farmers were defined by the General Agreement on Tariffs and Trade (1994) and EC Regulation 1783/03 and restricted Glastir participants from

[221] Natural Resources Wales, "Glastir Woodland Scheme," (last updated 10/25/21; accessed 10/25/21), https://naturalresources.wales/guidance-and-advice/business-sectors/forestry/woodland-creation/glastir-woodland-scheme/?lang=en.
[222] Llywodraeth Cymru, " Co-design for a Sustainable Farming Scheme for Wales," 33-39 (2021), https://gov.wales/sites/default/files/publications/2021-09/sustainable-farming-scheme-co-design-future-farming_0.pdf. [*hereafter* Co-design for SLM Scheme]
[223] *see* Wyne-Jones at 80.
[224] *see* SLM Scheme at 10.
[225] *see* GMEP Final Report at 6.
[226] *see* Entry Book 1 at 25.
[227] *see* Reed et al. at 1.
[228] *see* Entry Book 1 at 4.
[229] *see* Wyne-Jones at 80.
[230] *see* Entry Book 1 at 40.
[231] *see* Wyne Jones at 77.

Appendix V: Glastir

1. **Basic Program Information (cont'd)**
   - **Payment mechanism (cont'd)**:
     receiving payments for quantified outcomes.[232] These circumstances are changing following Brexit.[233]

     CAP is designed around two "pillars": Pillar 1 provides direct payments to farmers and other forms of market support, with the goal of building a strong agricultural sector. The smaller Pillar 2 is designed to support rural development.[234] Pillar two contains three "axes," and Glastir is subject to "axis 2" which is aimed at improving land management and the environment.[235]
   - **Average payment:** Farms generally receive £1,000 and £10,000 annually [2017 information].[236]
   - **Total payments/percentage of budget towards payments**: "Overall, 63% of Pillar 2 funding was spent on AES (2.2% in admin support) and 23% in support of production with the remainder split on administration (3.2%), forestry creation and restoration (8.4%) and support for social enterprises (2.4%)."[237] "Biodiversity...(including woodland habitats) accounts for 47% of the total GMEP budget, 36% is allocated across soils, waters, climate change mitigation, landscape and historic features, trade-offs and co-benefits, and the remaining 17% allocated to underpinning activities such as informatics, the GMEP data portal and project management."[238]

2. **History/Brief Overview**
   Glastir built off four pre-existing schemes.[239] WAG introduced Glastir in 2009 to strike a new path in Wales' environmental agenda that would tackle climate change, carbon capture, and water management.[240] As an important note for the Vermont PES Working Group as it considers funding, relationships to other programs, etc., all of Wales' agri-environment schemes in practice until that time were replaced by Glastir.[241]

   Glastir's design holds "a broad 'All-Wales Element' open to all farmers [working] alongside more specified 'Targeted', 'Regional', and 'Common-Land' elements to address areas of particular concern and tackle the issues of grazing commons."[242] Originally, farmers participating in Glastir operated in a point system where they chose different management options to reach a total number of points.[243] The program has since changed and "points are now attached to new management specifications explicitly designed to deliver benefits framed as 'environmental/ecosystem goods and services'."[244]

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[232] *Id.* at 81. "*So, whilst it has not yet been possible to change the basis of the payments, due to the requirements of EC Regulation 1783/03 which sets out income-foregone as the basis of agri-environment rates, it is evident that the Glastir payments are not being presented as a means of compensating farmers, but as a means of paying for a desirable product.*"
[233] David Arnott, David Chadwick, Ian Harris, Aleksandra Koj, & David L. Jones, "What can management option uptake tell us about ecosystem services delivery through agri-environment schemes?," *Land Use Policy,* 195 (2019). [*hereafter* Arnott et al.]
[234] *see* Reed et al. at 2.
[235] S.H. Gay, B. Osterburg, D. Baldock, A. Zdanowicz, "Recent evolution of the EU Common Agricultural Policy (CAP): state of play and environmental potential," *Impact of Environmental Agreements on the CAP*, 7 (2005), https://ieep.eu/uploads/articles/attachments/a9e24479-e35a-40ad-8c71-82f4401d4c68/WP6D4B_CAP.pdf?v=63664509697.
[236] *see* GMEP Final Report at 11. "*Environmental payments to farms in Wales average between <1 and 10% of total farm output, and are highest for hill cattle and sheep farms*."
[237] *see* Arnott et al. at 196.
[238] *see* GMEP Final Report at 7.
[239] *Id.* at 10.
[240] *see* Wyne-Jones at 80.
[241] *Id.*
[242] *Id.*
[243] *Id.*
[244] *Id.*

Appendix V: Glastir

2. **History/Brief Overview (cont'd)**

As of 2012, participants are required to enter all eligible land that they have full management control over.[245]

3. **Program Process**

Details of application, prerequisites, baseline assessments, objectives, payment calculation, etc.

i. *Pre-implementation of project/funding*[246]

Farm participants need to adhere to a Whole Farm Cost that "concerns record keeping and habitat protection, and prohibits some practices such as application of livestock manures when soils are waterlogged."[247] Participants begin in a General Entry (scheme), with later options of progressing to and Advanced (GA) scheme that spatially targets specified conservation issues. The program also includes a Commons element (GC), an Efficiency capital grant element (GF) and Organic Farming element (GO), and a Woodland Creation and Management element (GW) that stands alone as a separate program.

ii. *Project implementation*

Details of actions by participants/funder.

Participants must register an expression of interest, following which they will be asked to provide documentary evidence concerning management control of the land.[248] Participants will receive a package listing all parcels indicated in the expression of interest, which will include certain land characteristics and information to help choose options.[249] (Farms entering a Regional package will receive 10% more points per option (regional packages offer a reduced list of options that are considered of the greatest environmental value to a given region).[250] Participants then choose among management options and select at least enough to meet the points threshold.[251] A contract binding the agreement is signed following a discussion with a Divisional Office representative of the location and options selected.[252]

iii. *Details of monitoring, reporting, payment process.*

Glastir participants are required to allow government representatives to conduct on farm inspections to "check the land details and accuracy of any relevant documentation and record keeping."[253] Inspections are spread throughout the year and will cover all commitments that can be checked at the time of the visit.[254] In some cases, the inspections will conduct unannounced inspections.[255]

Payments are "calculated based on the eligible payable area under contract upon successful validation of the SAF and Glastir Contract each year."[256]

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[245] *see* SLM Scheme at 3.
[246] *see* GMEP Final Report at 10.
[247] *Id.*
[248] *see* SLM Scheme at 3-5.
[249] *Id.* at 5.
[250] *Id.* at 3
[251] *Id.* at 5. *See also*: Entry Book 1 at 3.
[252] *see* SLM Scheme at 5.
[253] *see* Entry Book 1 at 25.
[254] *Id.*
[255] *Id.*
[256] *Id.* at 4.

Appendix V: Glastir

4. **Concerns/Issues**

The program initially showed low participation rate, which farmers attributed to poor support and access to technical advice.[257] Although the project is not yet completed, it will phase out in 2024-25 when the Welsh Government plans to overhaul the country's environmental farm support schemes to replace with a comprehensive "Sustainable Farming Scheme for Wales."[258] Glastir was evaluated through surveys with participants and areas identified for improvement are listed below.

The prevailing issues reported in farmer surveys concern communications between administrators and participants.[259] In an assessment of Welsh farmers' experiences Glastir, many reported that they found the program too prescriptive and did not offer opportunities for farmers to offer their input.[260] Furthermore, the schemes were too inflexible to accommodate variability from weather, markets, etc.[261] The program's payment of £35 per hectare is contingent on reaching that point total.[262] Farmers stated that future schemes should include informed discussions with participants to clearly explain the objectives and reasons for implementing particular measures.[263]

Survey participants also reported a desire for better access to information and support, and that the program could be adapted to better accommodated peer-to-peer knowledge exchange and collaboration on common land.[264] Many also indicated that access to grant funding was necessary to overcome up-front costs for implementing best-practice measures and installing infrastructure.[265]

[257] Debbie James, "Glastir uptake hampered by lack of advice," *Farmers Weekly,* (October 16, 2012), https://www.fwi.co.uk/news/environment/glastir-uptake-hampered-by-lack-of-advice.
[258] *see* Co-design for SLM Scheme at 33-39.
[259] *Id.*
[260] *Id.*
[261] *Id.*
[262] *Id.*
[263] *Id.*
[264] *Id.*
[265] *Id.*

Appendix VI: Lake Taupo Nitrogen Trading Program

1. Basic Program Information

- **Program name:** The Lake Taupo Nitrogen Market in New Zealand
- **Program location**: Lake Taupo catchment area, NZ[266]
- **Year founded**: 2011[267]
- **Size of program (# of nitrogen trades.)**[268]:
  - 180 farmers enrolled as of 2015
  - 24 trades to Lake Taupo Protection Trust (LTPT) amounting to 170,300 kg N
  - 12 trades to other farmers amounting to 17,634 kg N
  - Total: 36 trades amounting to 187,934 kg N
- **Acreage of program**: N/A
- **Minimum acreage required**: N/A
- **Program administrator:** Lake Taupo Protection Trust
- **Targeted participants:** Farmers
- **Prerequisites for enrollment:** Compliance-based not voluntary
- **Required data sharing**: Based around livestock numbers and cropping practices, with all farms providing their annual accounting records to the Regional Council[269].
- **Budget (overall, annual, etc.)**: 79.2 million NZD
- **Funding source/who pays**[270]:
  - Taupo District Council (22%)
  - Waikato Regional Council (33%)
  - Central Government (45%)
- **Duration of program:** 2011-present
- **Goal/expected outcome(s):** 20% nitrogen reduction through the buy-back of allocated nitrogen discharge allowances and to reduce the local economic and social impacts of the nitrogen cap. The initial target of 153 tons of nitrogen reduction was raised to 170 tons. This goal was achieved in 2015[271].
- **Specific conservation practices mentioned/measured:** N/A
- **Ecosystem services measured:** Nitrogen load reduction
- **Method of ecosystem services measurement:** OVERSEER model estimates nitrogen emissions based on livestock numbers, fertilizer applied and management practices[272].
- **Practice or performance:** Performance
- **What is paid for:** Land, NDAs (nitrogen discharge allowances)
- **Payment (cost) per unit of service:** $300 per kg of N[273]
- **Payment mechanism:** Landowners were able to buy, sell, or lease nitrogen discharge allowances within the catchment.
- **Average payment:** N/A

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[266] Organisation for Economic Co-operation and Development. (2015). The Lake Taupo Nitrogen Market in New Zealand. *OECD Environment Paper*, *4*.
[267] Organisation for Economic Co-operation and Development. (2015). The Lake Taupo Nitrogen Market in New Zealand. *OECD Environment Paper*, *4*.
[268] *Id.*
[269] *Id.*
[270] *Id.*
[271] Organisation for Economic Co-operation and Development. (2015). The Lake Taupo Nitrogen Market in New Zealand. *OECD Environment Paper*, *4*.
[272] *Id.*
[273] *Id.*

Appendix VI: Lake Taupo Nitrogen Trading Program

1. **Basic Program Information (cont'd)**
   - **Selling point/tagline:** It is the only trading program or market where non-point sources operate under a cap[274].

2. **History/Brief Overview**

New Zealand's Lake Taupo Nitrogen Trading program was established as part of a policy package that addressed an emerging water quality problem, not an existing crisis, namely, to protect against deteriorating water quality of Lake Taupo. To achieve reduced nitrogen losses to 20% below current discharge levels, a catchment cap to constrain agricultural N load to Lake Taupo was established. To achieve this, a nitrogen discharge allowance (NDA) trading system and Lake Taupo Protection Trust (LTPT) 20% buy-back program were established.[275]

3. **Program Process**
   - **Pre-program implementation**
     i. Regulation of non-point agricultural sources: LTPT introduced land use and discharge controls whereby nitrogen leaching farming activities were now controlled through a resource consent and agricultural land now required a nitrogen discharge allowance (NDA) to farm.[276] NDAs for each farm were based on their highest nitrogen leaching year between 2001 and 2005. Nutrient leaching is determined using the OVERSEER nutrient budgeting model. This meant the activities on each consented farm could only leach as much nitrogen as the NDAs they were allocated. This is enforced through a requirement for approved management plans, a regular monitoring program, and penalties for non-compliance under the Resource Management Act.[277]
     ii. Based on NDAs, a nitrogen market was created which allows landowners to buy, sell, or lease other landowners' NDAs. Landowners could also sell their NDAs back to the LTPT, as described below.
     iii. LTPT buy-back: A public fund, managed by the LTPT, was established to permanently reduce nitrogen leaching in the catchment by at least 20% of current levels by 2020. This was through a mix of land purchase (and converting land use to low leaching activities) and directly purchasing NDAs (where farmers retain ownership of the land but change land use or management and receive a payment from the Trust)[278].

[274] Organisation for Economic Co-operation and Development. (2015). The Lake Taupo Nitrogen Market in New Zealand. *OECD Environment Paper*, *4*.
[275] *Id*
[276] *Id*
[277] Organisation for Economic Co-operation and Development. (2015). The Lake Taupo Nitrogen Market in New Zealand. *OECD Environment Paper*, *4*.
[278] *Id*

Appendix VI: Lake Taupo Nitrogen Trading Program

3. **Program Process (cont.)**

Table 2 | **History of nitrogen discharge allowance trades in the Lake Taupo**

Year	Number of trades to LTPT	Amount traded to LTPT (kg N)	Number of trades to farmers	Amount traded to farmers	Total trade	Total amount of N traded (kg N)
2009	3	17,242	3	12,184	6	29,426
2010	5	56,100	2	3,500	7	59,600
2011	4	43,614	2	1,311	6	44,925
2012	9	24,311	3	362	12	24,673
2013	2	9,799	1	113	3	9,912
2014*		0	1	164	1	164
2015	1	19,234	0	0	1	19,234
Total	**24**	**170,300**	**12**	**17,634**	**36**	**187,934**

Notes: * This represents the period to June 2014. LTPT = Lake Taupo Protection Trust.

Figure 1. History of nitrogen discharge allowance trades in the Lake Taupo, NZ catchment area as of 2015.

- **Post-project review and evaluation**
  - Highly successful in terms of reducing the amount of nitrogen leaving agricultural lands.[279]
  - The cap has reduced farmers' ability to intensify production, has
  - decreased land values and has significantly increased administration and compliance costs.[280]
  - A number of farmers left the area as a result of the project[281].
  - Overseer software will constantly need to be updated[282]
  - Attempt to minimize the administrative and time costs borne by farmers.[283]

4. **Concerns/Issues**

- No concrete or measured assessments of environmental impacts or cost/benefit to farmers.[284]
- High set-up and administration costs[285]
- High benchmarking costs for each farm[286]
- High consent application cost to farmers[287]
- Project's self-identified room for improvement.
- Externalities are difficult to identify[288]

[279] Duhon, M., McDonald, H., & Kerr, S. (2015). Nitrogen Trading in Lake Taupo An Analysis and Evaluation of an Innovative Water Management Policy. *Motu Economic and Public Policy Research*, *15*(7)
[280] *Id.*
[281] *Id.*
[282] *Id.*
[283] *Id.*
[284] *Id.*
[285] *Id.*
[286] Duhon, M., McDonald, H., & Kerr, S. (2015). Nitrogen Trading in Lake Taupo An Analysis and Evaluation of an Innovative Water Management Policy. *Motu Economic and Public Policy Research*, *15*(7)
[287] *Id.*
[288] *Id*

Appendix VII: Soil and Water Outcomes Fund (SWOF)

1.1 Basic Program Information

- **Location**: Particular counties in Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia (Chesapeake Watershed), Illinois, Iowa, Ohio
- **Year founded**: In 2019, SWOF launched a pilot project and in 2020 enrolled 9,500 acres in Iowa. In 2021, SWOF and partners expanded to 120,000 acres, primarily in Iowa, Illinois, and Ohio. In 2020, SWOF received $7.3 million from a USDA-NRCS grant (Regional Conservation Partnership Program Alternative Funding Arrangement) and received the same grant worth $8.5 million in 2021.[289, 290]
- **Program administrators**: AgOutcomes (subsidiary of Iowa Soybean Association) for "agronomic and farmer relations elements" and ReHarvest Partners (subsidiary of Quantified Ventures) for "financial and contracting aspects."[291] Additional support is provided by partners including the Agriculture Technology & Environmental Stewardship Foundation, American Farmland Trust, the Illinois Soybean Association, Ohio Corn & Wheat, and the Ohio Soybean Association. [292]
- **Size of program**: In SWOF's first year of implementation (2020) 9,500 acres were enrolled, 6,407 metric tons of CO2e were sequestered, 172,794 lbs of nitrogen were reduced, and 11,651 lbs of phosphorus were reduced.[293]

1.2 General Program Details

- **Program target participants:** Farmers in particular counties in Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia (Chesapeake Watershed), Illinois, Iowa, and Ohio.
- **Prerequisites for enrollment**: Must farm in a priority location and fields must be compliant with the USDA-FSA Highly Erodible Land and Wetland Conservation provisions. Participants may not enroll in other programs while participating in the SWOF. This includes cost-share.[294]
- **Required data**: Past two years of field management operations (records) .[295] Data is also collected on management operations during enrollment year(s).[296]
- **Length of contract**: 1 year, renewable[297]
- **Annual budget**: Depends on market and buyer. Although there is not a cap on acres per se, enrollment closes once SWOF reaches their acreage goal for the year.[298] There is no minimum or maximum number of acres required for enrollment.[299]

[289] Iowa Soybean Association. "USDA partnership will scale up Soil and Water Outcomes Fund's work with Midwest farmers." September 17, 2020. https://www.iasoybeans.com/newsroom/press-release/usda-partnership-will-scale-up-soil-and-water-outcomes-funds-work-with-midwest-farmers Accessed: October 18, 2021.
[290] Peabody, Rachel and Claire Weinzierl. Soil and Water Outcomes Fund Project Plans to Scale Up in Illinois, Indiana, And Missouri. Illinois Soybean Association. Press Release. October 8, 2021. https://www.ilsoy.org/press-release/soil-and-water-outcomes-fund-project-plans-scale-illinois-indiana-and-missouri Accessed: October 18, 2021.
[291] SWOF, "Our Partnership." Our Team. 2020. https://www.theoutcomesfund.com/team Accessed: October 18, 2021.
[292] *Id.*
[293] SWOF, "Our Impact." News + Impact. 2020. https://www.theoutcomesfund.com/impact Accessed: October 17, 2021.
[294] SWOF. "FAQ" Farmer Resources. 2020. https://www.theoutcomesfund.com/farmer-resources Accessed: October 17, 2021.
[295] Illinois Soybean Association. Soil and Water Outcomes Fund Virtual Q&A. Illinois Soybean Association. July 14, 2021. Soil and Water Outcomes Fund Virtual Q&A Accessed: November 16, 2021.
[296] *Id.*
[297] SWOF. "FAQ" Farmer Resources. 2020. https://www.theoutcomesfund.com/farmer-resources Accessed: October 17, 2021.
[298] SWOF. "FAQ" Farmer Resources. 2020. https://www.theoutcomesfund.com/farmer-resources Accessed: October 17, 2021.
[299] Illinois Soybean Association. Soil and Water Outcomes Fund Virtual Q&A. Illinois Soybean Association. July 14, 2021. Soil and Water Outcomes Fund Virtual Q&A Accessed: November 16, 2021.

Appendix VII: Soil and Water Outcomes Fund (SWOF)

1.2 General Program Details (cont'd)

- **Funding source**: Beneficiaries i.e. outcome customers[300] pay for services provided. Beneficiaries include corporations, municipalities, state departments of agriculture, and the federal government.[301] "…corporations seeking to offset greenhouse gas emissions in their supply chain, and public entities such as municipal water utilities or state departments of agriculture seeking to improve and safeguard water quality."[302] Customers include Cargill (April 2020), USDA, City of Ames™, Cedar Rapids "City of Five Seasons®", Iowa Department of Agriculture and Land Stewardship (February 2021), PepsiCo (April 2021), Nutrien Ag Solutions™ (February 2021), The County of Dubuque, Ingredion® (April 2021), and BASF.[303;304;305,306]
- **Payment mechanism**: SWOF "manages a pool of capital on behalf of impact investors to pay farmers for implementation of agriculture best management practices."[307]
- **Goals/expected outcome(s)**: SWOF seeks to have enrolled one million acres of US cropland by the end of 2023.
- **Accepted conservation practices**: SWOF is "not prescriptive about the conservation practices you can implement, participating farmers typically implement practices including no-till, cover crops, land retirement, conversion to pasture, extended rotations." [308] Compensation is affected by baselines practices and soil type. At a minimum, producers will need to use cover crops and reduce tillage or switch to no-till.[309]
- **Ecosystem services measured**: GHG outcomes (soil carbon sequestration and nitrous oxide reductions) and water quality improvements (nitrogen and phosphorus retention).

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[300] SWOF, About the Soil and Water Outcomes Fund. Factsheet. N.d. https://static1.squarespace.com/static/5db70c3d3a013f252a36f1da/t/5fa47860d690ab64102d406f/1604614304236/SWOF+One+Sheet+for+Beneficiaries Accessed: October 17, 2021.
[301] Kiel, Adam and Mark Lambert. Soil and Water Outcomes Fund Partners with Nutrien Ag Solutions to Launch Carbon and Water Quality Outcome Program. Press Release. February 9, 2021. https://www.theoutcomesfund.com/partnership-nutrien-ag-solutions-carbon-and-water-quality-outcome-program Accessed: October 17, 2021.
[302] SWOF, Cost-effective solutions for soil and water stewardship. Factsheet. April 2021. https://static1.squarespace.com/static/5db70c3d3a013f252a36f1da/t/608008e5a43e163b411979c9/1619003622559/SWOF+Farmer+One+Sheet+April+2021.pdf Accessed: October 17, 2021.
[303] SWOF, "Our Partnership." Our Team. 2020. https://www.theoutcomesfund.com/team Accessed: October 17, 2021.
[304] James, Katie, Keely Coppess, Adam Kiel, and Matt Lindsay. Iowa Department of Agriculture and Land Stewardship Announces Groundbreaking Water Quality Outcomes Incentives. Press Release. January 5, 2021. https://www.theoutcomesfund.com/idals-announces-groundbreaking-water-quality-outcomes-incentives Accessed: October 17, 2021.
[305] Kiel, Adam and Mark Lambert. Soil and Water Outcomes Fund Partners with Nutrien Ag Solutions to Launch Carbon and Water Quality Outcome Program. Press Release. February 9, 2021. https://www.theoutcomesfund.com/partnership-nutrien-ag-solutions-carbon-and-water-quality-outcome-program Accessed: October 17, 2021.
[306] Kiel, Adam and Mark Lambert. PepsiCo and Ingredion Partner with Soil and Water Outcomes Fund to Drive Carbon Sequestration and Water Quality Improvement Through Farmer-Centric Approach to Sustainable Agriculture. Press Release. April 21, 2021. https://www.theoutcomesfund.com/partnership-with-pepsico-ingredion-drives-carbon-sequestration-water-quality-improvement Accessed: October 17, 2021.
[307] SWOF. About the Soil and Water Outcomes Fund. Factsheet. N.d. https://static1.squarespace.com/static/5db70c3d3a013f252a36f1da/t/5fa47860d690ab64102d406f/1604614304236/SWOF+One+Sheet+for+Beneficiaries Accessed: October 17, 2021.
[308] SWOF, Cost-effective solutions for soil and water stewardship. Factsheet. April 2021. https://static1.squarespace.com/static/5db70c3d3a013f252a36f1da/t/608008e5a43e163b411979c9/1619003622559/SWOF+Farmer+One+Sheet+April+2021.pdf Accessed: October 17, 2021.
[309] SWOF. "FAQ" Farmer Resources. 2020. https://www.theoutcomesfund.com/farmer-resources Accessed: October 17, 2021.

Appendix VII: Soil and Water Outcomes Fund (SWOF)

1.2 General Program Details (cont'd)

- **Method of ecosystem services measurement**: Sustainable Environmental Consultants (SEC) provides third-party quantification and verification of environmental outcomes via the EcoPractices platform."[310] Soil and Water Outcomes Fund representatives also perform evaluations. Soil sample on 10% of farms, water sample on 10% of farms, remote sensing on 100% of fields, and staff conduct field inspections post-harvest.[311]

1.3 Payment Details

- **Practice or performance:** Performance[312]
- **Ecosystem services paid**: GHG outcomes (soil carbon sequestration and nitrous oxide reductions) and water quality improvements (nitrogen and phosphorus retention).
- **Payment (cost) per unit of service**: Payments are only offered if there is a guaranteed outcomes purchaser. [313] SWOF provides "payments to farmers and landowners that go well beyond the scale of existing public or private incentive programs."[314]
- **Average payment**: The average payment in 2020 was $35/acre.[315] The highest payment was $50 in 2020.[316] Payments vary by location/program. 2021 payment cap in Illinois was $20.[317] See Figure 2 for SWOF's side-by-side comparison of with other PES programs.[318]

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[310] SWOF, "Our Partnership." Our Team. 2020. https://www.theoutcomesfund.com/team Accessed: October 17, 2021.
[311] Illinois Soybean Association. Soil and Water Outcomes Fund Virtual Q&A. Illinois Soybean Association. July 14, 2021. Soil and Water Outcomes Fund Virtual Q&A Accessed: November 16, 2021.
[312] SWOF, "SWOF Original: Why Should Food and Agricultural Business-Related Companies Pay for Outcomes? (vs. Pay for Practices)." News + Impact. September 14, 2021. https://www.theoutcomesfund.com/in-the-news/swof-original-why-should-food-and-agricultural-business-related-companies-pay-for-outcomes-vs-pay-for-practices Accessed: October 17, 2021.
[313] SWOF. "FAQ" Farmer Resources. 2020. https://www.theoutcomesfund.com/farmer-resources Accessed 10.17.2021.
[314] SWOF, "Why Work with Us?" Homepage. 2020. https://www.theoutcomesfund.com/ Accessed: October 17, 2021.
[315] SWOF, "SWOF Original: Why Should Food and Agricultural Business-Related Companies Pay for Outcomes? (vs. Pay for Practices)." News + Impact. September 14, 2021. https://www.theoutcomesfund.com/in-the-news/swof-original-why-should-food-and-agricultural-business-related-companies-pay-for-outcomes-vs-pay-for-practices Accessed: October 17, 2021.
[316] Iowa Soybean Association. "Soil and Water Outcomes Fund." State of Soy. November 4, 2020. https://www.youtube.com/watch?v=4WJv_MTlYZs Accessed Accessed: October 17, 2021.
[317] Illinois Soybean Association. Soil and Water Outcomes Fund Virtual Q&A. Illinois Soybean Association. July 14, 2021. Soil and Water Outcomes Fund Virtual Q&A Accessed: November 16, 2021.
[318] SWOF. "SWOF Original: Side-by-Side Comparison of Carbon and Water Quality Outcome Programs." News + Impact. August 16, 2021. https://www.theoutcomesfund.com/in-the-news/swof-original-side-by-side-comparison-of-carbon-and-water-quality-outcome-programs Accessed: October 17, 2021.

Appendix VII: Soil and Water Outcomes Fund (SWOF)

Soil and Water Outcomes Fund | **Carbon Credit & Water Outcomes Program Comparison**
Choosing the Right Ecosystems Services Program for Your Farm

	Soil and Water Outcomes Fund	Bayer	FarmersEdge	CIBO	Corteva	Nori	indigo	Gradable	Truterra
Payments for both carbon AND water quality.	✓								
Average payments above $35/acre.	✓								
Payments not contingent on carbon market. Farmer does not need to market their credits.	✓	✓			✓		✓		✓
First payment made at time contract is signed.	✓								
Contracts renewed/signed annually; no long-term contract.	✓			✓					
On-staff agronomist to assist with enrollment/practices.	✓	✓					✓		✓
Tenant/legal decision-maker able to enroll.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Monitoring and verification at no cost.	✓	✓			✓		✓		✓
No additional purchases, nor use of company's data tool, required to participate.	✓			✓		✓			

Figure 2. SWOF Side-by-Side Comparison of Carbon and Water Quality Outcome Programs.[319]

2. Program History

In 2013, Iowa implemented the Nutrient Reduction Strategy which resulted in the Iowa Water Quality Initiative (WQI) action plan. The Iowa Department of Agriculture and Land Stewardship (IDALS) supports SWOF through the WQI.[320] Initially piloted in Illinois, Ohio, and the Chesapeake region and first outcomes customers are Cargill (April 2020), followed by Nutrien Ag Solutions (February 2021). SWOF strives to offer "Cost effective solutions for soil and water stewardship."[321] SWOF "provides financial incentives directly to farmers who transition to on-farm conservation practices that yield positive environmental outcomes like carbon sequestration and water quality improvement. We provide significant per acre payments to farmers and landowners by selling these environmental outcomes to public and private beneficiaries."[322]

3. Program Process

- **Project funding:** Based on buyers and market.
- **Project application process:**
  1) create and map fields in SWOF portal and enter baseline and future cropping information, 2) review proposed payment (typically received within 1-2 weeks of signing up), 3) sign contract and receive 50% of payment to off-set investment costs, 4) receive TA from SWOF staff,

[319] SWOF. "SWOF Original: Side-by-Side Comparison of Carbon and Water Quality Outcome Programs." News + Impact. August 16, 2021. https://www.theoutcomesfund.com/in-the-news/swof-original-side-by-side-comparison-of-carbon-and-water-quality-outcome-programs Accessed: October 17, 2021.
[320] James, Katie, Keely Coppess, Adam Kiel, and Matt Lindsay. Iowa Department of Agriculture and Land Stewardship Announces Groundbreaking Water Quality Outcomes Incentives. Press Release. January 5, 2021. https://www.theoutcomesfund.com/idals-announces-groundbreaking-water-quality-outcomes-incentives Accessed: October 17, 2021.
[321] SWOF. "Why Work with Us?" Homepage. 2020. https://www.theoutcomesfund.com/ Accessed: October 17, 2021.
[322] *Id.*

Appendix VII: Soil and Water Outcomes Fund (SWOF)

3. Program Process (cont'd)

- **Project application process (cont'd):**
  5) receive 50% of payment at end of crop year after practice has been verified. Farmers may receive assistance from County coordinators.[323]
- **Monitoring, reporting, payment process**
  Sustainable Environmental Consultants (SEC) provides third-party quantification and verification of environmental outcomes via the EcoPractices platform."[324] Soil and Water Outcomes Fund representatives also perform evaluations. Soil sample on 10% of farms, water sample on 10% of farms, remote sensing on 100% of fields, and staff conduct field inspections post-harvest. [325] Quantified Ventures is able to show that their model can produce the same outcome as a municipality "with 30% less cost because they measure and sell the outcomes, rather than paying for the adoption of practices with less reliable tracking of outcomes."[326]
- **Post-project review and evaluation**
  SWOF was initiated in 2021 and it is too early to conduct an evaluation of the program.

4.1 Concerns/Issues

SWOF pays for transition to practices, but does not compensate for farmers who are already implementing conservation strategies. Measurement methods are not easily accessible. Publicization efforts are not clear i.e. strategy to let farmers know about the program is not explicit. Yearlong contracts means that there may not be consistency from year to year. (On the other hand, year-long contracts give farmers flexibility to enroll in PES with a different organization or take advantage of a more lucrative market. Shorter contracts may limit opportunity-cost.) The market is new, and prices guaranteed in the pilot program may not continue as the market fluctuates with supply and demand. SWOF does not detail it's long-term funding strategy. It is unknown how program will continue with just private investors (no government grants). Furthermore, it is not clear if farms can 'age out' by reaching plateau i.e. implementing practices no longer increase water quality or carbon storage. Details of payment structure are unknown and long-term expectations of carbon regulation companies (like Cargill) are unknown e.g. if regulations is not pressing, companies may reduce quantity of credits bought or offer lower payments.[327]

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[323] Hopper, Joseph. "Dubuque County farmers explain why they chose The Soil and Water Outcomes Fund." Iowa Soybean Association. August 19, 2021. https://www.iasoybeans.com/newsroom/article/dubuque-county-farmers-explain-why-they-chose-the-soil-and-water-outcomes-fund Accessed 10.17.2021.

[324] SWOF, "Our Partnership." Our Team. 2020. https://www.theoutcomesfund.com/team Accessed 10.17.2021.

[325] Illinois Soybean Association. Soil and Water Outcomes Fund Virtual Q&A. Illinois Soybean Association. July 14, 2021. Soil and Water Outcomes Fund Virtual Q&A Accessed: 16.11.2021

[326] Sworder, Chris. "Regenerative Agriculture – A New Asset Class for Agriculture and Nature-based Solutions Investors – Part 3." CleanTech Group. September 16, 2020. https://www.cleantech.com/regenerative-agriculture-a-new-asset-class-for-agriculture-and-nature-based-solutions-investors-part-3/ Accessed 10.18.2021.

[327] Janiec, Chris. "Cargill-backed pilot fund eyes private capital and 2021 launch." Agri Investor. April 23, 2020. https://www.agriinvestor.com/cargill-backed-pilot-fund-eyes-private-capital-and-2021-launch/ Accessed 10.18.2021.

Appendix VIII: Sustainable Farming Incentive

1. Basic Program Information

- **Program name**: Sustainable Farming Incentive
- **Program location**: England[328]
- **Year founded**: 2021[329]
- **Size of program** (# of farms, landowners, etc.): 938 farmers for the pilot[330]
- **Acreage of program**: N/A
- **Minimum acreage required**: N/A
- **Program administrator**: Department for Environment, Food & Rural Affairs
- **Targeted participants**: Farmers
- **Prerequisites for enrollment**[331]:
    - Eligible Basic Payment Scheme (BPS) applicant in 2020 or 2021
    - Be registered on the Rural Payments service
    - Is not common land or used for shared grazing
    - Does not have an existing agri-environment agreement on it[332]
    - Must have management control of the land included in agreement[333]
- **Required data sharing:** Required documentation to show farmers are meeting the mandatory actions.
- **Budget:**
    - $2.4 billion from 2021-2025[334]
    - $1.6 billion on direct payments[334]
- **Funding source/who pays:** Department for Environment, Food & Rural Affairs
- **Duration of program**: Pilot (2021-2024) Project (2024-2027)[335]
- Additional payments: Learning activities are expected to take up to 15 hours a month. Each pilot participant will be paid $5,000 for the first year of the pilot. Payments making up this total will be made quarterly[336].
- **Goal/expected outcome(s)**[337]:
    - clean and plentiful water
    - clean air
    - thriving plants and wildlife
    - protection from environmental hazards
    - reduction of and adaptation to climate change
    - beauty, heritage and engagement with the environment
- **Specific conservation practices mentioned/measured:** Too many to list, including reduced tillage, riparian buffer installation, etc.[337]
- **Ecosystem services measured**: Too many to list, including pollinator habitat, flood mitigation, etc.[337]

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[328] Department for Environment, Food & Rural Affairs. (2021). *Guidance Sustainable Farming Incentive pilot*.
[329] *Id.*
[330] *Id.*
[331] *Id.*
[332] *Id.*
[333] *Id.*
[334] *Id.*
[335] *Id/*
[336] *Id/*
[337] *Id.*

Appendix VIII: Sustainable Farming Incentive

1. Basic Program Information (cont'd)

- **Practice or performance**: Practice bundles and monitoring/recordkeeping
- **What is paid for**: Proper implementation of conservation strategies
- **Payment (cost) per unit of service**: Depends on "levels" achieved for eight "standards"[338]
- **Payment mechanism:** Payments will be made for all the eligible land in the agreement and all actions have to be completed on all that land.[339]
- **Average payment**: N/A
- **Total payments/percentage of budget towards payments**: 67%[340]

2. History/Brief Overview

The Sustainable Farming Incentive scheme is one of 3 schemes being developed to encourage environmental land management.[341] The other schemes are Local Nature Recovery and Landscape Recovery. The Sustainable Farming Incentive scheme will reward farmers for managing their land in an environmentally sustainable way.[342] These schemes will operate together and pay for sustainable farming practices, improve animal health and welfare, improve environmental outcomes, and reduce carbon emissions.[343] They will create habitats for nature recovery and make landscape-scale changes such as establishing new woodland and other ecosystem services, providing key means to deliver against the country's 25 Year Environment Plan goals and carbon net zero targets.[344] The full scheme will launch in 2022, initially for farmers in England who currently get payments under the Basic Payment Scheme (BPS).[345]

3. Program Process

- Farmer selects land registered on your Rural Payments service account.[346]
- Farmer then selects Sustainable Farming Incentive 'standards' to apply to eligible land and to other features, like hedgerows.[347]
- Farmer also chooses an ambition level for each standard. If you select a higher level, you'll be paid more.[348]

  Ex. Arable and horticultural soils standard
  - Farmer selects the Arable and horticultural soils standard
  - Farmer decides to strive for the Introductory level which has an associated payment of $26 per hectare (2.45 acres)[349]
  - Farmer will be paid for all the eligible land that's in the agreement and will have to complete the actions on all that land.[350]
  - For this standard at the Introductory level, there are four mandatory actions[351]

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[338] Department for Environment, Food & Rural Affairs. (2021). *Guidance Sustainable Farming Incentive pilot*.
[339] *Id.*
[340] *Id.*
[341] *Id.*
[342] *Id.*
[343] Applin, L., & Lewis, T. (2021). *Update on the Sustainable Farming Incentive pilot*. https://defrafarming.blog.gov.uk/2021/10/15/update-on-the-sustainable-farming-incentive-pilot/
[344] *Id.*
[345] *Id.*
[346] Department for Environment, Food & Rural Affairs. (2021). *Guidance Sustainable Farming Incentive pilot*.
[347] *Id.*
[348] *Id*
[349] *Id*
[350] *Id*
[351] *Id.*

Appendix VIII: Sustainable Farming Incentive

3. **Program Process (cont.)**

Ex. Arable and horticultural soils standard (cont'd)

- Carry out a soil assessment
- Alleviate soil compaction
- Establish green cover
- Add soil organic matter

- Farmer will keep documents to show they are meeting the mandatory actions[352]
- Farmers will submit an annual declaration which confirms progress under your agreement up to that point.[353]
- Department for Environment, Food & Rural Affairs will be reviewing delivery of agreement through a combination of:[354]
    - physical and virtual site visits
    - remote monitoring
    - desk-based administrative checks

4. **Concerns/Issues (from reported feedback thus far)**

Application guidance
Some farmers struggled to use guidance online and would have preferred printable versions.[355]

Application process
Those who attended a Defra pre-recorded webinar better understood how to apply.[356]

Support
Over 700 farmers reached out for assistance to the Rural Payments Agency.[357]

Data
Several farmers spotted out-of-date information online and they found the process to update data complex and difficult to navigate.[358]

Usability of the pilot application service
There were challenges with the online application portal.[359]

Standard fit
Some farmers struggled to fit the standards to their farms. The description of the standards felt too inflexible.[360]

Payments
Some people were put off from doing more because the payment rates were considered an insufficient incentive.[361]

[352] Department for Environment, Food & Rural Affairs. (2021). *Guidance Sustainable Farming Incentive pilot*.
[353] *Id.*
[354] *Id.*
[355] Applin, L., & Lewis, T. (2021). *Update on the Sustainable Farming Incentive pilot*. https://defrafarming.blog.gov.uk/2021/10/15/update-on-the-sustainable-farming-incentive-pilot/
[356] *Id.*
[357] *Id.*
[358] *Id.*
[359] *Id.*
[360] *Id.*
[361] *Id.*

Appendix IX: Truterra

1.1 Basic Program Information

- **Location**: Varies.
- **Year founded**: 2016[362]
- **Program administrator**: Truterra LLC is the sustainability business of Land O'Lakes.
- **Size of program**: 1,840,000 acres are enrolled on 1,900 farms[363]
- **Affiliates**: For a full list of partners, see list at the end of Appendix IX.

1.2 General Program Details

- **Program target participants:** Farmers, Agricultural Retailers, Food & CPG Companies 2016.[364]
- **Prerequisites for enrollment**: No prerequisites or minimum acres specified.
- **Required data**: Historical data is not required for general use, but three years of baseline data is required for those enrolled in carbon transaction programs.[365] Truterra uses a combination of publicly available data and propriety algorithms.[366]
- **Length of contract**: Varies by program with potential to renew.
- **Annual budget**: Not specified.
- **Funding sources**: Licensees (ag retailers and other users) and businesses who wish to meet Social Responsibility Practitioner (SRP) or environmental goals. Typically, corporations either make payment based on insetting (when companies reduce emissions within own supply chain) or offsetting (when companies purchase carbon credits).[367]

  Funding my also come from government agencies. For example, in the Dubuque County's Pay-For-Performance Program, funding is secured through the Stewardship Incentive Program in partnership with Truterra, Dubuque Soil and Water Conservation District, and local Truterra ag retailer Innovative Ag Services.[368,369] Truterra also collaborates with the National Fish and Wildlife Foundation, National Association of Conservation Districts, and its retailer network to enable conservation agronomist positions at select retailers to provide conservation technical assistance.[370, 371]
- **Payment mechanism**: Payment may depend on buyer or program. For example, in the Dubuque County Pay-For-Performance Program, farmers received an average of $33/acre for climate and water benefits achieved.[372]

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[362] Truterra. Homepage. 2021. https://www.truterraag.com/ Accessed: November 3, 2021.
[363] *Id.*
[364] Id.
[365] Truterra. "TRUCARBON™ OFFER FAQ." 2021. https://www.rivervalleycoop.com/getattachment/c368016d-294f-4cea-99e8-3a6b6b19e8c3/TruCarbon-Program-FAQ.pdf?lang=en-US Accessed: November 30, 2021.
[366] Truterra. Homepage. 2021. https://www.truterraag.com/ Accessed: November 3, 2021.
[367] Truterra. "The Rapidly Evolving Carbon Market in Agriculture an Overview in Questions & Answers." Carbon Market Q&A. October 2020. https://www.truterraag.com/getattachment/1a0ed799-881e-422e-9c43-7fa7abf8281b/Carbon-Market-QA_October-2020.pdf?lang=en-US&ext=.pdf Accessed: November 7, 2021.
[368] Truterra. "Dubuque County Pay-For-Performance Program, Powered by Truterra, Improves Water Quality, Shifts Participating Acres to Carbon Negative." Articles. October 6, 2021. https://www.truterraag.com/articles/dubuque-county-pay-for-performance-program,-powere Accessed: November 6, 2021.
[369] Truterra. "Truterra Partners with Dubuque County, IA to Offer Local Growers Financial Incentives for Sustainability Improvements." Articles. February 23, 2021. https://www.truterraag.com/Articles/Truterra-Partners-with-Dubuque-County,-IA-to-Offer Accessed: November 6, 2021.
[370] Truterra. "National Fish and Wildlife Foundation, Truterra, LLC Invest to Bolster on-the-ground Conservation Expertise Available to Farmers." Articles. 2021. https://www.truterraag.com/Articles/National-Fish-and-Wildlife-Foundation,-Truterr-(1) Accessed: November 7, 2021.
[371] Truterra. "Building Bridges Between Communities." Articles. 2021. https://www.truterraag.com/Articles/Building-Bridges-Between-Communities Accessed: November 7, 2021.
[372] Truterra. "Dubuque County Pay-For-Performance Program, Powered by Truterra, Improves Water Quality, Shifts Participating Acres to Carbon Negative." Articles. October 6, 2021. https://www.truterraag.com/articles/dubuque-county-pay-for-performance-program,-powere Accessed: November 6, 2021.

Appendix IX: Truterra

1.2 General Program Details (cont'd)

- **Goals/expected outcome(s)**: Truterra is a data collecting and modeling software platform that can be utilized by different entities. Hence the goals and payments depend on the entities relying on Truterra for data management and impact of agronomic practices. In the Dubuque County Pay-For-Performance Program "Participating acres were net carbon negative, sequestering nearly 2x as much GHG in 2021 as emitted in 2020."[373] See Program History for more information on specific success stories.
- **Accepted conservation practices**: Conservation practices that improve sustainability include cover cropping, reducing tillage, and extended crop rotations (from the typical two to three), improved nitrogen management, utilizing variable rate technology.[374]
- **Ecosystem services measured**: Soil carbon accumulation is measured by soil testing, farmer interviews, and other data sources.[375] Truterra's modeling platform offers insights on erosion prevention, sequestering carbon, improving soil health, reducing nutrient loss which effects, risk of leaching, nitrogen use efficiency performance, greenhouse gas performance, and greenhouse gas sequestration which impact water supply and air quality.[376,377]
- **Method of ecosystem services measurement**: Truterra uses a hybrid approach to measure carbon, utilizing stratification soil sampling and modeling.[378] Soil modeling uses algorithms and data (soil type, weather data, tillage patterns, and cover crops) to estimate soil carbon.[379] Computer-based models estimate a national average 0.2-0.5 tons/acre/year carbon removal when no-till and/or cover crops are implemented.[380] For buyers, the Truterra platform offers a "soil to certification approach," but Truterra's definition of soil health is unspecified.[381] The Truterra sustainability tool is positioned to offer other types of ecosystem credits (e.g. water quality and quantity) in the future as well.[382]

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[373] *Id.*
[374] Truterra. "The Rapidly Evolving Carbon Market in Agriculture an Overview in Questions & Answers." Carbon Market Q&A. October 2020. https://www.truterraag.com/getattachment/1a0ed799-881e-422e-9c43-7fa7abf8281b/Carbon-Market-QA_October-2020.pdf?lang=en-US&ext=.pdf Accessed: November 7, 2021.
[375] Truterra. "The Process of Transforming On-Farm Stewardship into Farm-Generated Carbon Credits." Truterra Carbon Credit V1. n.d. https://www.truterraag.com/getmedia/2f784735-b827-4a65-8e41-8bfdbd5c3924/Truterra-carbon-credit-v1.pdf Accessed: Accessed: November 6, 2021.
[376] Truterra. "How can Truterra help our food system become more transparent?." Truterra YouTube Channel. 2021. https://www.youtube.com/watch?v=xFplNH4GkCM Accessed: November 6, 2021.
[377] Truterra. "The Truterra™ Insights Engine." Truterra YouTube Channel. January 18, 2021. https://www.youtube.com/watch?v=3f_TaEdWQ4s Accessed: November 6, 2021.
[378] Wells, Jennifer. "How is soil carbon measured? And how much is it worth?" In Touch & In Tune. Truterra. February 2021. https://www.truterraag.com/getmedia/99c331a5-fcfe-4095-9298-cec54c05efed/February-Issue_2021.pdf Accessed: November 6, 2021.
[379] *Id.*
[380] *Id.*
[381] Truterra. "Streamlining the path to agricultural carbon and ecosystem services markets." Carbon Program. 2021. https://www.truterraag.com/Carbon Accessed: November 6, 2021.
[382] *Id.*

Appendix IX: Truterra

1.3 Payment Details

- **Practice or performance:** Payments are based on modeling, testing, and/or performance.
- **Ecosystem services paid**: Carbon sequestration as far back as five years.[383]
- **Payment (cost) per unit of service**: In February 2021, Truterra launched its carbon credit program, offering participating farmers $20/ton of carbon and extending that payment back as far as five years to qualifying farmers.[384]
- **Average payment**: Payment depends on market and buyer. The majority of carbon credits sold are between $10-15, but can be as little as $3 or as much as $47.[385] The current Truterra payment of $20 is considered generous for today's market.[386;387]

2. Program History

Truterra is the product of a farmer-owned cooperative seeking ot increase conservation on the ground and private companies wanting to increase their social and/or social responsibility reputation i.e. meet their sustainable development goals (SDG). Jason Weller, then Truterra Vice-President, now President stated, "As private sector demand for on-farm stewardship continues to grow, we're proud to partner with world-class companies like Corbion to bring new resources and new opportunities directly to farmers and their local ag retailers."[388]

The Truterra program was launched by Land O'Lakes in 2016 and since its inception, more than 40 agriculture retailers have joined the network which reflects the current 1,900 farms and 29,000 fields enrolled in the Truterra sustainability tool. Combined, Truterra and Land O'Lakes "touch 25% of all row crop farmers and 50% of the harvested acres."[389] Truterra "is the leading farmer-driven ag and food sustainability program in the U.S."[390] 1,840,000 acres have been put through the Truterra platform.[391] Nineteen states have participating farms.[392] For example, in the Dubuque County Pay for Performance program, payments were made for adopting advanced nutrient management systems (1,591 new acres), adopting cover crops (1,175 new acres), and adopting no-till (183 new acres) which reduced nitrogen loss by an average of 21.9 lbs/acre, phosphorus loss by 2.67 lbs/acre, and reduction of sheet and rill erosion by 14%.[393] In 2021, Truterra announced a partnership with Verdesian Life Sciences to trial their Trident™ nitrogen stabilizer and Verdesian's SEED+™ Liquid and Take Off ST® seed treatments to accelerate cover crop establishment.[394]

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383 Truterra. "Streamlining the path to agricultural carbon and ecosystem services markets." Carbon Program. 2021. https://www.truterraag.com/Carbon Accessed: November 6, 2021.
384 Truterra. "Northern Country Coop Joins Farmer-Owned Truterra Network to Bring New Sustainability and Profitability Opportunities to Local Growers." Articles. 2021. https://www.truterraag.com/articles/northern-country-coop-joins-farmer-owned-truterra Accessed: November 6, 2021.
385 Wells, Jennifer. "How is soil carbon measured? And how much is it worth?" In Touch & In Tune. Truterra. February 2021. https://www.truterraag.com/getmedia/99c331a5-fcfe-4095-9298-cec54c05efed/February-Issue_2021.pdf Accessed: November 6, 2021.
386 *Id.*
387 Truterra. "Northern Country Coop Joins Farmer-Owned Truterra Network to Bring New Sustainability and Profitability Opportunities to Local Growers." Articles. 2021. https://www.truterraag.com/articles/northern-country-coop-joins-farmer-owned-truterra Accessed: November 6, 2021.
388 Truterra. "Corbion teams with Truterra, farmers to advance sustainable agriculture." Articles. 2021. https://www.truterraag.com/articles/corbion-teams-with-truterra-farmers-to-advance-su Accessed: November 7, 2021.
389 Truterra. Homepage. 2021. https://www.truterraag.com/ Accessed: November 3, 2021.
390 *Id.*
391 Truterra. Farming and Production Organizations. 2021. https://www.truterraag.com/Farming-Production-Organizations Accessed: November 4, 2021.
392 Truterra. "The future of conservation and sustainability is PRECISION." Truterra YouTube Channel. January 12, 2021. https://www.youtube.com/watch?v=gXM4JsoGVj0 Accessed: November 6, 2021.
393 Truterra. "Dubuque County Pay-For-Performance Program, Powered by Truterra, Improves Water Quality, Shifts Participating Acres to Carbon Negative." Articles. October 6, 2021. https://www.truterraag.com/articles/dubuque-county-pay-for-performance-program,-powere Accessed: November 6, 2021.
394 Truterra. "Verdesian Life Sciences and Truterra Team Up to Advance On-Farm Sustainability Across U.S." News. 2021. https://www.truterraag.com/Articles/Verdesian-Life-Sciences-and-Truterra-Team-Up-to-Ad Accessed: November 4, 2021.

Appendix IX: Truterra

2. **Program History (cont'd)**
Truterra is a sustainability tool that provides an online, interactive, live digital platform that allows farmers and their agronomic advisor to virtually trial different management practices (or suites of practices) and compare results for nitrogen efficiency, soil health insights, and sustainability scores or stewardship ranking, or otherwise maximize return on investment on a field-by-field basis.[395,396] Truterra can manage farmer data required to enter markets, helps farmers identify cost share opportunities by working with local, state, and federal agencies, prepare for new markets (e.g. carbon and water quality credits), and share their positive land stewardship story with the community.[397,398] Truterra's modeling software provides data-backed insights to make better informed management decisions.[399]

In 2018, a pilot program in the Chesapeake Bay was launched with partnerships among Truterra, Campbell Soup Company, and the The Mill (Land O'Lakes agricultural retailer). Over the course of a year, participating farmers saw their Truterra sustainability score jump six points due to improved adoption of conservation practices like planting cover crops, implementing no-till, and utilizing nitrogen efficiency strategies.[400] This is part of Campbell's SDG goal of sustainably sourcing 50% of their wheat by 2025.[401] This program began on 10,000 acres in the Chesapeake region in 2017 and in 2019 expanded to an additional 60,000 acres in Ohio with Heritage Cooperative, thus meeting Campbell's 70,000 acre goal in 2020, one year ahead of schedule.[402] Also in 2018, Tate and Lyle in partnership with Truterra launched a demonstration project that initially enrolled 310,000 acres in corn production in the US Midwest, but since then has expanded to 1.5 million acres in corn production which has helped achieve a 10% reduction in greenhouse gas emissions, 38% increase in nitrogen use efficiency, 6% reduction in sheet and rill erosion, and 4% improvement in soil conditioning index.[403]

As part of the INfield Advantage program, Truterra has partnered with Indiana Soybean Alliance (ISA), Indiana Department of Agriculture in a cover crop demonstration trial that tracks the benefits on fields that have never been cover cropped.[404] Farmers receive a $200 sign-up incentive, free cover crop seed, free soil testing and access to the Truterra sustainability tool.[405] The program is funded through USDA Natural Resources Conservation Service, ISA, and Indiana Corn Marketing Council checkoff dollars.[406] Truterra has also partnered with INfield for cover crop trials, split nitrogen application trial, and tillage methods on 40-80 acre fields, offering $200 signing bonus after data is entered, free soil health tests,

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[395] Truterra. Farming and Production Organizations. 2021. https://www.truterraag.com/Farming-Production-Organizations Accessed: November 4, 2021.
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[402] *Id.*
[403] Truterra. "Responsible production starts with responsible sourcing." Tate & Lyle Sustainable Agriculture Programme. n.d. https://admin.truterraag.com/getmedia/82e6e55e-d976-4a1d-aa18-b32fdbbae3d1/Tate-Lyle-sustainable-agriculture-programme.pdf?ext=.pdf Accessed: November 6 2021.
[404] Truterra. "INfield Advantage enrollment open for Indiana farmers to test drive cover crops." Articles. 2021. https://www.truterraag.com/articles/infield-advantage-enrollment-open-for-indiana-farm Accessed: November 7, 2021.
[405] *Id.*
[406] *Id.*

Appendix IX: Truterra

2. Program History (cont'd)

routine soil tests, and tissue sampling (not for tillage method trial).[407] The INfield Advantage program, as a result of partnering with Truterra, has also partnered with two of Truterra's agricultural retailers, Ceres Solutions and Premier Ag.[408] Truterra is one of Field to Market® Qualified Data Management Partners, has integrated the Field to Market® suite of sustainability metrics into Truterra software, is integrated into Field to Market® Fieldprint calculator, supports multiple Field to Market® projects, over 1,600 farmers, and over 1.5 million acres.[409,410] Truterra's partnership with Tate and Lyle is through Field to Market®.[411]

3. Carbon Program Process

- **Project application process:**
  Truterra offers a short (5-6 question) survey for carbon farmers to see if Truterra's offerings are a suitable fit.[412] [413]
- **Project implementation**
  Truterra retailers assist farmers in data collection and ongoing conservation planning with an eye toward carbon sequestration.[414, 415,416] For example, in September 2020, "the U.S. Business Roundtable publicly released 11 policy principles aimed at achieving the goals of the Paris Agreement" and the GHG Protocol, a global GHG accounting standard, "Sustainability commitments related to GHG emissions are categorized as Scope 1, Scope 2 or Scope 3." [417]

  Truterra's process is as follows: 1) "Farmer implements practices to increase soil carbon levels." 2) "Aggregator collects field-level data to quantify soil carbon." 3) "Soil carbon amounts confirmed via soil testing, farmer interviews, other data sources." 4) "Verified data is evaluated against carbon market certification standards plus any buyer requests." 5) "Certified carbon credits owned by farmer or aggregator are made available to buyer(s) and purchase is transacted." 6) "Farmer maintains stewardship records."[418]

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407 INfield Advantage. "Get an INfield Advantage." Trials. 2021. https://infieldadvantage.org/trials/#nutrient-inputs-trial Accessed: November 7, 2021.
408 Truterra. "INfield Advantage enrollment open for Indiana farmers to test drive cover crops." Articles. 2021. https://www.truterraag.com/articles/infield-advantage-enrollment-open-for-indiana-farm Accessed: November 7, 2021.
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411 Field to Market. Member Spotlight: Truterra. 2021. https://fieldtomarket.org/featured-member-spotlight-series/truterra/ Accessed: November 7, 2021.
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413 Truterra. "We're delivering sustainability that's truly sustainable." Food and CPG Companies. 2021. https://www.truterraag.com/Food-CPG-Companies Accessed: November 6, 2021.
414 Truterra. "How can Truterra help our food system become more transparent?." Truterra YouTube Channel. 2021. https://www.youtube.com/watch?v=xFplNH4GkCM Accessed: November 6, 2021.
415 Truterra. "Truterra Partners with Dubuque County, IA to Offer Local Growers Financial Incentives for Sustainability Improvements." Articles. February 23, 2021. https://www.truterraag.com/Articles/Truterra-Partners-with-Dubuque-County,-IA-to-Offer Accessed: November 6, 2021.
416 Truterra. "The Truterra™ Insights Engine." Truterra YouTube Channel. January 18, 2021. https://www.youtube.com/watch?v=3f_TaEdWQ4s Accessed: November 6, 2021.
417 Truterra. "The Rapidly Evolving Carbon Market in Agriculture an Overview in Questions & Answers." Carbon Market Q&A. October 2020. https://www.truterraag.com/getattachment/1a0ed799-881e-422e-9c43-7fa7abf8281b/Carbon-Market-QA_October-2020.pdf?lang=en-US&ext=.pdf Accessed: November 7, 2021.
418 Truterra. "The Process of Transforming On-Farm Stewardship into Farm-Generated Carbon Credits." Truterra Carbon Credit V1. n.d. https://www.truterraag.com/getmedia/2f784735-b827-4a65-8e41-8bfdbd5c3924/Truterra-carbon-credit-v1.pdf Accessed: November 6, 2021.

Appendix IX: Truterra

3. **Program Process (cont'd)**
   - **Project implementation (cont'd)**
     Truterra offers a quick sustainability score option that allows farmers not working Truterra retailers to see how their fields rank, but does not provide any of the modeling or conservation scenario options.[419] Currently, two companies have purchased licenses to the quick stewardship score software.[420] EFC has incorporated Truterra's quick stewardship score into its FieldAlytics software and AGI has incorporated it into its SureTrak management system.[421]
   - **Monitoring, reporting, payment process**
     Monitoring, reporting, and payment process depend on the buyer. The verification method is not explicitly stated. The Truterra sustainability tool helps farmers manage data, generate data, and aggregates farmers data the positive impacts of which can be shared with buyers.[422] Farmers own data "at all times."[423]
   - **Post-project review and evaluation**
     Post-project review and evaluation was not publicly available at the time of writing this report. Anecdotally, Truterra reports that farmers appreciate having field data to make decisions with and receive new data.[424]

4. **Concerns/Issues**
   Depending on the program, only additionality is paid for. Corporate software could promote corporate solutions that prioritize corporate profit over real conservation changes as could be the case with Land O'Lakes Truttera partnership with Verdesian.

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[419] Truterra. "How quick sustainability scores are generating renewed interest in conservation." Articles. 2021. https://www.truterraag.com/articles/how-quick-sustainability-scores Accessed: November 7, 2021.
[420] *Id.*
[421] *Id.*
[422] Truterra. "How can Truterra help our food system become more transparent?" Truterra YouTube Channel. 2021. https://www.youtube.com/watch?v=xFplNH4GkCM Accessed: November6, 2021.
[423] Truterra. "Star of the West Milling Co Joins Farmer-Owned Truterra Network to Bring New Sustainability and Profitability Opportunities to Local Growers." Articles. 2021. https://www.truterraag.com/articles/star-of-the-west-milling-co-joins-farmer-owned-tru Accessed: November 7, 2021.
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Appendix IX: Truterra

List of partners:[425]

- Ag Growth International (AGI)
- Colorado State University
- Corbion
- Cotton®
- Cotton Incorporated®
- U.S. Cotton Trust Protocol®
- EFC Systems™
- Microsoft
- National Association of Conservation Districts
- NRCS
- Campbells
- Minnesota Department of Agriculture
- Tate & Lyle
- Tavant
- Walmart
- Northland Capital Equipment Finance
- Soil Health Institute
- Agriculture's Clean Water Alliance
- Ducks Unlimited
- Iowa Agriculture Water Alliance
- INfield Advantage
- Soil and Water Conservation Society
- National Fish and Wildlife Foundation
- AGCO
- California Bioenergy
- Nestle PURINA
- Environmental Initiative
- Environmental Tillage Systems
- Field to Market
- Iowa Soybean Association
- La Crosse SEED
- Pheasants forever The Habitat Organization
- Minnesota University
- USDA
- Cannon River Agriculture Collaborative (public, private, and non-profit) for water quality improvements[426]
    - Central Farm Service
    - Cannon River Watershed Partnership
    - Rice SWCD
    - Steele SWCD
    - Cannon River 1 Watershed 1 Plan
    - Minnesota Agricultural Water Quality Certification Program
    - Great River Greening
    - Environmental Initiative
    - Jennie-O
- National Association of Conservation Districts[427]

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[425] Truterra. Homepage. 2021. https://www.truterraag.com/ Accessed: November 3, 2021.
[426] Truterra. "Working Together to Protect Water in Minnesota." Articles. 2021. https://www.truterraag.com/Articles/Working-Together-to-Protect-Water-in-Minnesota Accessed: November 6, 2021.
[427] Truterra. "Building Bridges Between Communities." Articles. 2021. https://www.truterraag.com/Articles/Building-Bridges-Between-Communities Accessed: November 7, 2021.

Appendix IX: Truterra

List of partnering retailers[428]

- Ag Valley Co-op
- Alliance Ag & Grain
- Battle Creek Farmers Pride
- Belgrade Coop
- Central Farm Service
- Central Valley Ag
- Centra Sota Cooperative
- Ceres Solutions
- Chandler Coop
- Cooperative Farmers Elevator
- Country Partners Inc
- Equity Exchange
- Farmers Cooperative Society
- Farmward
- Five Star Cooperative
- Frontier Cooperative
- Great Bend Co-op
- GreenPoint Ag
- Heartland Co-op
- Heritage Cooperative
- Innovative Ag Services
- Innovative Ag Services - CA
- Kaup Seed and Fertlizer
- Key Cooperative
- Landus Cooperative
- Linn Co-op Oil Company
- Mercer Landmark
- Midland Marketing Coop Inc
- MKC
- New Vision Cooperative
- Northern Country Co-op
- North Star Cooperative
- NuWay-K&H Cooperative
- Ottawa Cooperative Association
- Pathway Ag
- Premier Ag
- Pride Ag
- Reddy Ag Service, Inc & Ross Soil Service, LLC
- River Valley Cooperative
- Scott Cooperative Association
- Smith Fertilizer and Grain
- Star of the West
- The Mill
- Twin State Inc.
- Vision Ag LLC
- WESTCO
- Windy Ridge Ag

[428] Personal communication with Jill Wheeler, Truterra Senior Manager Public Affairs. January 21, 2022..

Appendix X. Vermont Pay for Phosphorus Program

1. Basic Program Information

- **Program name**: Vermont Pay-For-Phosphorus (VT PfP) Program
- **Program location**: Vermont, USA[429]
- **Year founded**: 2021[429]
- **Size of program (# of farms, landowners, etc.)**: Farms will apply for enrollment in the late Fall of 2021. Target of 100 farms over the course of four years. [429]
- **Acreage of program**: N/A
- **Minimum acreage required**: No[429]
- **Program administrator:** Vermont Agency of Agriculture, Food and Markets Water Quality Division[429]
- **Targeted participants**: Eligible farms statewide that meet the RAP Threshold Criteria with crop or hay acres under management.
- **Prerequisites for enrollment**[429]:
    - Actively farming in Vermont
    - All fields managed by the farm
    - Annual cropland and/or hayland
    - Up-to-date Nutrient Management Plan that meets the standards for their farm size in the RAPs.
    - Good Standing with the VAAFM for state environmental regulations, including VT's Required Agricultural Practices (RAPs) and federal Highly Erodible Land (HEL) and Wetland Conservation Compliance.
- **Acceptance guaranteed after enrollment:** No.
    - Ranking pools will support the greatest percentage of funding for Lake Champlain Basin and the Lake Memphremagog Basin, with some funding set aside for watersheds outside of these Basins. [429]
    - Prioritize applicants with higher % of P-reductions and historically underserved farmers. [429]
    - If farms do not rank out, or do not demonstrate reductions above the regulatory threshold, referred to the Farm Agronomic Practices (FAP) Program or other payment programs. [429]
- **Required data sharing:**
    - Initially enter the whole farm's planned nutrient management for the coming year into the FarmPREP program. [429]
    - By the end of the calendar year the farms will (with the help of TA providers as needed) update FarmPREP to reflect their implemented stewardship and Qualified third parties will verify this implementation. [429]
- **Funding source/who pays:** Farmers will enter into contracts with and receive funding from VAAFM. These payments will be financially supported by the USDA Natural Resources Conservation Service (NRCS) Regional Conservation Program (RCPP) Alternative Funding Arrangement (RCPP-AFA) [429]
- **Budget:**
    - $7 million grant from NRCS[429]
    - $4.9 in payments to VT farmers over five years. [429]

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[429] Agency of Agriculture, Food and Markets. (2021). *The Vermont Pay-For-Phosphorus (VPFP) Program Overview*. https://agriculture.vermont.gov/sites/agriculture/files/documents/VPFP_Overview_FAQs.pdf

Appendix X. Vermont Pay for Phosphorus Program

1. Basic Program Information (cont'd)

- **Duration of program:** Five years[430]
- **Goal/expected outcome(s):**[431]
    - Reduce phosphorus loading by an estimated 40,000 lbs.
    - 100 farms enrolled
    - Farmer autonomy in decision-making
    - $4.9 million in payments to farmers
- **Specific conservation practices mentioned/measured**: Practices that are able to be modeled in FarmPREP include nutrient management, crop rotations, conversion to hay, cover crop, reduced tillage, no till, manure incorporation or injection, buffers, and grassed waterways.
- **Ecosystem services measured**: Phosphorus load reduction
- **Method of ecosystem services measurement**: P runoff will be modeled from historic TMDL management scenarios and compared with current management. Resulting net P runoff reductions across the farm that exceed the established threshold will receive a payment per pound of P.[432]
- **Practice or performance:** Performance
- **Enrollment payment:** Yes. Initial Data Entry Payment will be $15 per acre with a cap of $4000 per farm. Data Entry Payment compensates the farmer for their time entering or working with TA providers.[433]
- **Other additional incentive payments:** No
- **What is paid for**: Net pounds of P reduced across the farm beyond the threshold reductions.[434]
- **Payment (cost) per unit of service**: TBD
- **Payment mechanism:** Payment will be made after the growing season is finished.[435]
- **Average payment:** TBD
- **Total payments/percentage of budget towards payments**: $4.9 million, or 70% of the budget is expected to be spent on payments to farmers.[436]
- **Selling point/tagline**: Innovative pay-for-performance approach.

2. History/Brief Overview

The Vermont Pay-For-Phosphorus (VPFP) Program, funded by the USDA NRCS RCPP AFA program, will build a novel Pay-for-Performance program in the State of Vermont that will pay for phosphorus reductions above the Lake Champlain Basin Phosphorus TMDL reduction requirements[437]. This strategy comes in response to the state's need to address issues of non-point source pollution and excess nutrient runoff into Lake Champlain and other bodies of water.[438]

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430 Agency of Agriculture, Food and Markets. (2021). *The Vermont Pay-For-Phosphorus (VPFP) Program Overview*. https://agriculture.vermont.gov/sites/agriculture/files/documents/VPFP_Overview_FAQs.pdf
431 *Id.*
432 *Id.*
433 *Id.*
434 *Id.*
435 *Id.*
436 *Id.*
437 *Id.*
438 *Id.*

Appendix X. Vermont Pay for Phosphorus Program

3. **Program Process**

- **Pre-implementation of project/funding**
  i. Eligible land is "Annual Cropland" and "Hay Land". Farms statewide that are in good standing with AAFM, meet NRCS requirements, and have an up-to-date NMP are eligible.[439]
  ii. To encourage farmers to apply to the program and enter their data in FarmPREP, AAFM will offer a one-time Initial Data Entry Payment to all new applicants. In the first year this will be $15 per acre with a cap of $4000 per farm. Farms enter the whole farm's planned nutrient management for the coming year into FarmPREP in winter.[440]
  iii. Priority given to the Lake Champlain Basin and to the Lake Memphremagog Basin. Ranking will prioritize applicants with a higher net percentage of P-reductions across the farm and historically underserved farmers. If farms do not rank out, or do not demonstrate reductions above an additionality threshold set by VAAFM, they will be referred to other existing payment programs that may be able to support practice implementation.[441]
  iv. Successful applicants will be notified and invited to enroll in early spring.[442]
- **Project implementation**
  i. Annually, farms will apply in January. VAAFM and NRCS will screen applicants for eligibility. Eligible first-time applicants will receive a contract for Data Entry Payment, and work with a TA provider to enter their farm maps and planned land management into the FarmPREP tool. Once that is complete, those farms will receive a Data Entry Payment and all farms/entries will be ranked. A subset of farms will be offered a contract for the rest of the year for implementation of the plan as described in FarmPREP.[443]
  ii. Detail of monitoring, reporting, payment process
    1. Enrolled farms will implement conservation practices in the growing season and will work with TA providers to update FarmPREP accordingly.[444]
    2. Qualified third parties will verify the implementation and FarmPREP records.[445]
    3. Farms will be paid for the pounds of P they reduce above min. Program thresholds at the growing season's end.[446]

4. **Concerns/Issues**

- Almost at time of implementation for the first round of applications and there has yet to be a determination for the payment per lb. of P.[447]
- Preference to Lake Champlain Basin and Lake Memphremagog watershed may be seen as unfair.[463]
- May push farmers into addressing a state resource concern (phosphorus loading) that they are not directly connected to or see as an issue affecting their area.[463]

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[439] Agency of Agriculture, Food and Markets. (2021). *The Vermont Pay-For-Phosphorus (VPFP) Program Overview*. https://agriculture.vermont.gov/sites/agriculture/files/documents/VPFP_Overview_FAQs.pdf
[440] *Id.*
[441] *Id.*
[442] *Id.*
[443] *Id.*
[444] *Id.*
[445] *Id.*
[446] *Id.*
[447] *Id.*

Appendix Q

The University of Vermont

Farmer PES Program Proposals

Vermont Payment for Ecosystem Services Technical Research Report #6 B

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

December 2021

Prepared by: Christopher Bonasia, Guy Choiniere, Scott Magnan, Stephen Leslie

Gund Institute for Environment

The University of Vermont Extension

SECTION 1: INTRODUCTION

The aim of this project is to summarize three farmer-drafted proposals for designing a Vermont Payment for Ecosystem Services (PES) program and compare those programs with the VT PES Technical Research Report #6 to the Vermont Soil Health PES Working Group. The three proposals summarized here are:

1. CSP+, presented by Guy Choiniere
2. VT PES Observed Metrics Approach, presented by Scott Magnan
3. VT Healthy Soil Protection & Restoration Act, presented by Stephen Leslie

As directed by the VT PES Working Group, this review was completed to assist the Working Group's framing of a VT-focused PES. All three farmers presented their proposals to the VT PES Working Group. The information included in this summary was collected through documents drafted by the farmers, presentations given to the Working Group, and personal interviews with the farmers. Information about other programs that relate to the farmer proposals was gathered during research for the Task 6 PES Program Review. Accordingly, readers of this report may want to reference the Task 6 report.

Following this Introduction, Section 2 of this report summarizes how each of the programs address the criteria included in the program tables. A discussion in Section 3 will compare the farmer proposals to existing PES programs, and Section 4 will consider how the three proposals compare with the recommendations presented in the Task 6 program review.

SECTION 2: PROGRAM REVIEW

2.1 PES Program Background

All three programs were designed and presented to the Working Group at different times. Though all programs lay out a concept for design, none have comprehensively established all criteria and are still open for editing and suggestions. Some important remaining open questions across all three programs include how they will be funded, how much farmers should be paid for ecosystem services, and what farmers should be eligible for participation.

1. <u>CSP+</u>

The CSP+ proposal was initially introduced in May 2021 by Guy Choinere to the Vermont Small Farm Group. Feedback from the Working Group and farmers was incorporated into the proposal and presented to the Working Group in July and October 2021.

CSP+ aims to supplement existing conservation programs by addressing the gaps and shortcomings experienced by farmers and identified by the Working Group. CSP+ particularly considers supplementing the Conservation Stewardship Program (CSP) administered by the Natural Resource Conservation Service, but could either alternatively or additionally supplement other existing programs like the Environmental Quality Incentives Program (EQIP).

The proposal suggests a $10,000 base payment to participating farmers who then additionally receive per-acre payments reflecting different 'tiers' of stewardship that are defined by various practices and performance metrics. This is different from the CSP program, which does not offer different tiers of stewardship. Additionally, CSP does not offer a base payment and instead distributes payments on a per acre basis, though it does ensure a minimum payment of $1,500 per year and a maximum of $40,000 per year, regardless of acreage. Critically, Guy Choinere says that the intent of the proposal is that the state is not meant to take on the full expense of the program, and as a supplement to federal programs would only cover expenses to fill in the gaps of existing programs.

2. VT PES Observed Metrics Approach

The VT PES Observed Metrics Approach was drafted by Scott Magnan and aims to 1) "identify (enroll) farms that have a high aptitude for building soil health," 2) "reward the farms that are both economically and environmentally sustainable," 3) "use metrics that can be done at the farm level," and 4) "encourage collaboration between farmers and TSPs." Scott Magnan submitted a document outlining his proposal and held a discussion with members of the Working Group in October 2021 and gave a public presentation to the entire Working Group in December 2021.

The Observed Metrics Approach uses a point-based system informed by categories of measured outcomes to reflect stewardship of up-to-15 acre management zones. The payments are determined by the total number of points multiplied by the number of acres within the management zone. Contrary to the other two proposals, the Observed Metrics Approach pays strictly for outcomes and places the burden of risk, and responsibility for coordinating measurements, on the participating farmer.

3. VT Healthy Soil Protection & Restoration Act (VT HSP&R Act)

The VT HSP&R Act was drafted by Stephen Leslie as an approach for the state of Vermont to meet the greenhouse gas emission reduction targets established in the VT Global Warming Solutions Act by "[elevating] healthy soil as an essential ingredient to solve the climate and ecological crisis." The proposal aims to be a "progressive soil health policy reflective of a radical shift in societal priorities---where soil is recognized as 'basic infrastructure.'" Stephen Leslie submitted a document outlining his proposal to the Working Group in October 2021 and presented the proposal to the Working Group in December 2021.

The VT HSP&R Act would begin with a phased transition for agriculture and forestry by implementing Soil Health Management Systems to restore soil health to pre-human-degradation levels. The proposal would rely on collaboration with a fortified network of Conservation Districts to coordinate teams of experts to work with land managers to implement and troubleshoot conservation strategies. Incentives would be based on implemented practices determined through a comprehensive management plan.

2.2 Program Management

All three proposals suggest a program that is government run. All programs envision substantial involvement by technical service providers and state agencies—none identify a specific organization to administer the program, though the VT HSP&R Act considers Conservation Districts for this role.

2.3 Program Market Scope

All proposals are intended to be voluntary and funded by the Vermont State Government, though the Observed Metrics Approach considers eventually adapting to participate in an ecosystem services market.

2.4 Eligibility

The Observed Metrics Approach is unique among the proposals in that everyone can participate and there are no eligibility requirements. However, the structure of the point system makes it nearly impossible for individuals that don't meet certain criteria to perform well. For instance, in the case that a farm is not RAP compliant or does not keep its lands in production, that farm will immediately lose 20% of its possible final score and will at best be able to achieve the lowest payment rate ($50/acre) if they have no other point reductions; losing only an additional 5 points will cause the farm to receive no compensation at all.

The other two proposals require RAP compliance, and CSP+ requires that the farmers collaborate with technical service and business advisors to develop a comprehensive farm-management plan (the VT HSP&R Act also suggests a strong holistic planning element). While both programs are specific to agricultural and managed forest land, the vision for the VT HSP&R Act is envisioned to eventually extend to other sectors and include all landowners that can generate ecosystem services.

2.5 Pay for Practice or Pay for Performance

All three proposals include elements of outcome quantification, but in different ways.

CSP+ includes opportunities for compensation linked to both practices and performance, though performance-based payments are only included in the upper two tiers (note that these tiers still also include practice-based payments).

The Observed Metrics Approach pays strictly for measured outcomes (though it does include a deduction for a percent of impervious land area without including any quantified impacts on ecosystem services from that area) and does not specify any practices.

The VT HSP&R Act pays for practices but envisions measuring outcomes on a selection of pilot farms to ensure the effectiveness of different practices for improving Vermont soil health and inform planning for other farmers.

2.6 Required Data & Verification Methods

Though neither the CSP+ or VT HSP&R Act have specific data requirements, the emphasis that both proposals place on comprehensive planning with technical service providers indicates that farmers will be required to share a wide range of relevant information with advisors. The Observed Metrics Approach will require soil samples, profit and loss statements, measurements from a soil test pit, and possibly NDVI data.

All proposals include a 3rd party verifier to establish confidence and trustworthiness in the program. Though none of the proposals concretely specify a 3rd party, all consider the potential for verification from other farmers or from technical service providers (CSP+ and the VT HSP&R Act emphasizes a role for Conservation Districts). The Observed Metrics Approach also considers having Crop Advisors perform verifications.

The VT Healthy Soil Protection & Restoration Act and CSP+ proposals both envision annual verifications. The Observed Metrics Approach would allow for different verification schedules for different management structures—while most farms would be verified annually, some farm-types (like permanent hay or sugaring) could be verified less-than annually for some or all metrics.

2.7 Payments

In addition to a $10,000 per year base payment, the CSP+ program provides per-acre payments of $10, $60, and $90 for Steward, Soil Builder, and Regenerative management tiers, respectively.

Payments in the Observed Metric Approach are determined by the total number of points achieved by the farmer, with a possible total of 100 points; payments are distributed on a per-acre basis. Farms reaching less than 75 points receive no compensation; farms reaching between 75-80 points receive $50; farms between 85-90 points receive $150; farms between 90-95 points receive $350; and farms that achieve over 95 points receive $500.

The payment rates for the VT Healthy Soil Protection & Restoration Act are still to be determined.

SECTION 3: DISCUSSION

The three farmer proposals each offer unique approaches to compensating farmers for building and maintaining ecosystem services through land stewardship. Among the three proposals, the Observed Metrics Approach is distinct from the other two in many ways, while CSP+ and the HSP&R Act share many attributes; in fact, Mr. Leslie has stated that he thinks his proposal is "completely compatible" with CSP+.

All three programs base payments on an assumed overall benefit for society, but do not base payments on a quantified social gain (such as avoided costs)—in this way they are similar to all programs in the Task 6 Program Review.

1. CSP+

The CSP+ proposal is unique from the other programs by using state funding to supplement federal programs to fill any gaps in eligibility and equity. Though the baseline payment's ambition is also not reflected in other programs, the intent to include an up-front payment that reduces the risk to farmers in performance-based programs is also included in the VT PfP program and, in some cases, the TruTerra program.

The tiered payments associated with levels of stewardship in this proposal is most similar to the payment scheme of the Sustainable Farming Incentive. However, offering payments for both practices and performance is not shown in the other reviewed programs.

In the tiers where CSP+ offers practice-based payments the potential breadth of eligible practices makes it similar to the large-government run programs like CSP, Glastir, and the Sustainable Farming Incentive. Because of this, the program would need to be carefully designed so that, as it strives to fill in the gaps of the existing programs, it does not perpetuate the inflexibility, poor communication, and overly prescriptive issues raised by participants of those programs.

2. Observed Metrics Approach

The Observed Metrics Approach and Glastir both use point-based systems to determine compensation. The differences in how the point systems are used reflect the overall differences between the two programs. Both designs link compensation directly to the number of points accrued by the landowner, but as a practice-based program participants in Glastir aim for a fixed, predetermined number of points at the time of their enrollment to later receive a fixed, predetermined payment. In the Observed Metrics Approach, however, points are counted at the end of a verification cycle and reflect the farmer's actual performance to determine payments, and those payments can be increased or lowered.

One unique element of the Observed Metrics Approach is the Oak tree test, which assumes that the soil around an Oak tree will indicate the best possible soil health measurements for each farm's conditions (Scott Magnan suggests changing this to a Maple tree test, to be more reflective of Vermont). The proposal overall does not include baseline measurements and suggests paying farmers to meet thresholds consistent across all participants. The reliance on threshold measurement exposes the Approach to the general concerns raised about threshold-based programs, like being inequitable for farms with certain soil types that may struggle more to meet a given threshold. However, the Oak tree test offers a way to set a threshold that will be unique to each farm and can therefore account for environmental factors that would disadvantage some farmers. Though the Oak tree test is currently included as a bonus opportunity and would account for a small amount of total possible points, Scott Magnan said he has considered weighing this test more heavily in the proposal.

Of the ten programs reviewed in the Task 6 report only Lake Taupo and VT PfP also combine payments for performance with threshold measurements. Unlike the Observed Metrics Approach, these two programs use modelling software to project (rather than directly measure) outcomes. Both of these programs are different from this proposal in that they focus on one specific outcome. Additionally, Lake Taupo and VT PfP both focus on meeting a threshold for reducing a metric that is linked to reducing and ecosystem disservice (nitrogen and phosphorus pollution, respectively) rather than measuring the growth of an ecosystem metric.

3. <u>HSP&R Act</u>

Although the HSP&R Act proposal does not intend to pay for outcomes, Stephen Leslie would like the program to measure outcomes on a selection of pilot farms in each watershed. Though these farms would not receive payments on the measured outcomes, the data would be used to ensure that the practices are resulting in the expected improvements and inform how practices are implemented on other farms. This aspect of the proposal is similar to Glastir's 'Glastir Monitoring & Evaluation Programme.

Like CSP+, the focus on paying for a wide-range of pre-determined practices echoes the large-government run programs like CSP, Glastir, and the Sustainable Farming Incentive, and the proposal would need to be carefully designed to avoid the complaints raised by participants in those programs (inflexible, overly prescriptive, poor communication to farmers).

SECTION 4: PES PROGRAM RECOMMENDATIONS

The Task 6 PES Program Review identified six components of successful PES programs. This section will briefly consider how each farmer proposal addresses these components.

1. <u>Prioritizing Fairness</u>

The Task 6 Program Review defined a fair program design as one that addresses several issues of access, communication, and eligibility. Some of these issues must be considered by administrators (such as publicization & communication), but the farmer proposals offer some valuable ideas for fair implementation. All farmers propose improved and effective communication between participants and administrators to overcome the communication issues identified in programs like Glastir.

CSP+ is in many ways designed around program fairness, as one of its primary objectives is to act as a supplement to the Conservation Stewardship Program that addresses gaps in access and equity. The proposal specifically aims to include farms that are excluded by the current ranking system. CSP+ also suggests supporting new and historically underserved farmers by offering an increased payment rate for farmers that enroll in a 'beginner farmer reserve program' that "[allows] an HU farmer to bid on a farm before it gets put onto the open market."

The Observed Metrics Approach has no eligibility requirements, but the design of the program will make it difficult for some farmers to participate if they have not already invested in soil health. Even though some farms will have great difficulty, by not including any strict eligibility requirements for the program. leaves the door open to ingenious solutions to meet the program objectives in unanticipated and flexible ways.

The HSP&R Act does not detail any specific actions for fairness but notes that a program will need to consider site characteristics and context to account for the varying conditions between farms. Additionally, because Stephen Leslie suggested that his proposal is fully compatible with CSP+, the HSP&R Act could also encompass the fairness measures listed for that program.

2. Hybridizing compensation in a tiered approach to include pay for practice and performance

Of the three programs, CSP+ is the only one that already lays out a tiered approach to include pay for practice and performance, though it deviates by also offering a base payment (but it should be noted that the base payment is not incompatible with a tiered program design). The HSP&R Act does not specifically suggest such an approach, but Stephen Leslie's statement that his program is compatible with CSP+ indicates that his proposal could still incorporate that approach. The Observed Metrics Approach is more strictly focused on offering payments and likely would not incorporate a tiered payments system that pays for both practices and performance.

3. Establishing Credibility

The proposals do not explicitly address credibility concerns. However, they do all encourage strong support for technical support services, along with other farmers, to be engaged in the program, which could contribute to the program's overall credibility. Additionally, all three proposals suggest third party verification measures.

Other measures of credibility depend on the monitoring and verification tools used in the program. CSP+ and the HSP&R Act do not directly specify particular metrics or measuring tools, so ensuring credibility will depend on identifying the best available options to include in those programs.

The Observed Metrics Approach does lay out several metrics and measuring tools to be used, and one of the great strengths of this proposal lies in the credibility gained by using straightforward, clearly defined metrics that offer little room for varying interpretations.

4. Guaranteeing Longevity

None of the farmer proposals have identified a particular contract length. They all aim to offer long-term incentives for farmers, but through different mechanisms. The CSP+ as well as the HSP&R Act could accommodate multi-year contracts. The Observed Metrics Approach could give farmers a continued opportunity to evaluate and score their soils. Stephen Leslie emphasizes permanence's importance in his proposal and notes its implications for equity, where he states that "carbon farming is a long-term proposition. Land managers willing and able to practice regenerative principles and practices will require a steady guaranteed income. Every farm will experience ebbs and flows in sequestration, but there is not a farm in Vermont that can't build more soil organic matter. It is this cumulative effect that is exponentially important and why payment should be equitable across the board for all land managers participating in soil health management regardless of acreage or income."

Longevity of any program will depend on a permanent and consistent funding source for a PES program, which still needs to be identified.

5. Administering through a government to create demand

All proposals already envision beginning as state government administered programs.

6. Identifying whether determine payments based on baseline on threshold measurements

The Task 6 PES Program review identifies that a decision to use baseline or threshold measurements will depend on other factors of program design. The CSP+ and HSP&R Act proposals could currently accommodate either, and because of the blended approach to pay for both performance and practices will probably also use both thresholds and baselines in different circumstances. The Observed Metrics Approach is based on using a threshold measurement (as discussed above), and by incorporating the Oak tree test, or stratifying thresholds by soil texture, could bridge some of the concerns about baseline measurements.

SECTION 5: CONCLUSION

The three farmer-drafted proposals include elements that are similar to existing programs and other elements that are entirely new or unique. These farmer-drafted proposals highlight the importance of measuring soil health, either as a foundation for payment rates or to verify outcomes. They also identify program elements and payment approaches that simplify some of the complexity inherent in a program that aims to reward multiple outcomes through the use of thresholds and scoring systems with a shared goal of rewarding farmers who achieve high outcome performance. The farmers highlight the importance of investing in communication with trusted partners and support initiatives to strengthen the role of technical service providers, conservation districts, extension and farmer-to-farmer knowledge exchange. All elements of these programs can be considered alongside the recommendations listed in the VT PES Technical Research Report #6 prepared for the Vermont Soil Health PES Working Group. Where these proposals echo existing programs, the Working Group can additionally look at the strengths and weaknesses of these existing programs to consider how these elements can add to a Vermont PES program design. Additionally, the unique attributes of the farmer proposals should be further explored to identify how these ideas can help bridge some of the outstanding questions regarding PES systems.

The University of Vermont

Whole Farm Net Zero:

Approaches to quantification of climate regulation ecosystem services at the whole farm scale

Vermont Payment for Ecosystem Services Technical Research Report #7

Version 2

Prepared for the Vermont Soil Health and Payment for Ecosystem Services Working Group

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GUND INSTITUTE FOR ENVIRONMENT

THE UNIVERSITY OF VERMONT EXTENSION

1) Introduction

In this report, approaches to the quantification of climate mitigation ecosystem services at the whole farm scale are reviewed and summarized for easy comparison. Eight quantification tools, and three case studies demonstrating possible tool applications, are summarized to fulfill the requirements of the Technical Services Contract—Task 7. Information from a combination of literature review and expert interviews served to document the inputs, outputs, strengths, weaknesses, opportunities, and threats for each quantification tool. This research was conducted in service to the Vermont Soil Health and Payment for Ecosystem Services (PES) Working Group (VT PES working group).[1] It is our hope that this report provides productive information and insights for the implementation of whole farm scale payment for ecosystem services programs, Vermont's Climate Action Plan, and similar efforts elsewhere.

Emissions reductions on farms are of interest to farmers in Vermont and will be required by the implementation of the Global Warming Solutions Act (GWSA).[2] Management changes that reduce emissions at the farm scale could possibly be supported and encouraged through a PES program. Given the work and goals of the PES Working Group and the requirements to implement the GWSA it is critical to understand the degree of accuracy and scope of currently available greenhouse gas assessment tools that could possibly be implemented to measure and monitor outcomes from VT agriculture.

Section 2 of this report describes the methods used to collect information reviewing eight tools for quantifying agricultural greenhouse gas emissions and sequestration rates, including the CarbOn Management & Emissions Tool (COMET)-Farm, COMET-Planner, COOL-Farm, DayCent, DNDC (DeNitrification-DeComposition), Environmental Policy Integrated Climate (EPIC) & APEX Agricultural Policy / Environmental eXtender (APEX), Holos, and the Integrated Farm Systems Model (IFSM). These eight tools were each reviewed using a systematic literature review, interviews with experts who are well-versed in using the specific tools, and a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis.

Section 3 presents some larger-context considerations for choosing an appropriate tool. Section 4 gives a high-level overview of the SWOT analysis performed for each tool reviewed for this task. Section 5 describes three example applications of emissions modelling tools. Section 6 contains concluding remarks. The report's Appendix section includes the SWOT analyses for each tool to allow for more in-depth review, as well as a series of tables to present a high-level comparison of the tools.

[1] State of Vermont Agency of Agriculture, Food & Markets, "Payment for Ecosystem Services and Soil Health Working Group," (2022), https://agriculture.vermont.gov/pes#:~:text=The%20purpose%20of%20this%20Working,reduce%20agricultural%20runoff%20to%20waters.
[2] Vermont Act 153 (2020), "Vermont Global Warming Solutions Act", https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT153/ACT153%20As%20Enacted.pdf

a) Framing for Vermont Soil Health & Payment for Ecosystem Services Working Group

Soils are the largest terrestrial sink of carbon and critical to global climate regulation. Protecting and managing soil carbon is a critical climate change mitigation strategy that will help meet state and national global greenhouse gas mitigation goals by supporting farmers to influence their overall impact on atmospheric greenhouse gas (GHG) concentrations through changes in soil management. However, soil and cropping management decisions are embedded within a complex decision-making context of the whole farm, and in many cases, management changes beyond soil and cropping practices have greater effects on overall net GHG balance.

Farms are managed as whole systems, where changes in one aspect of the farm have implications for other pieces of the system. Vermont farms manage more than just crop fields--they may also have substantial forested acreage, sugarbush, riparian areas, perennial plantings, and a diversity of animals.[3] In this way, farm management can provide many ecosystem services beyond producing food and fiber, and manure and feed management practices can have some of the biggest impacts on a farm's overall greenhouse gas emission levels.

While the PES Working Group explores options for expanding the scope of PES in Vermont from soil health within crop fields, to edge-of-field and whole farm perspectives, the complexity of quantifying performance for all ecosystem services of interest at the whole farm scale becomes overwhelming in complexity and scope. However, broken up into parts, this task becomes much more approachable. Climate regulation ecosystem services is a natural place to start as there are existing quantification tools and similar current interest across the globe. Should the PES working group maintain their focus on crop field soil health it will remain important to understand how that fits into whole farm net-zero assessments.

Approaches to incentivizing enhanced climate regulation in the agriculture sector advanced by the VT PES working group should align with those advanced to meet the 2020 GWSA as the state of Vermont begins to implement its Climate Action Plan. This necessitates a careful consideration of how the quantification tools available for farms comport, or don't, with international and state assessment standards. Notably, there is already acknowledgment that the Vermont emissions inventory protocol that is informing ongoing GWSA efforts at the state scale differs from international IPCC scientific standards and may not adequately assess the suite of interventions in agroecosystems that farms can use to influence greenhouse gas emissions and overall climate regulation ecosystem services. Additionally, alignment with other emerging whole farm carbon accounting efforts by industry and the federal government should align as much as possible.

[3] Ryan Patch, "Agriculture Soil Health Co-benefits," presented to VT PES & Soil Health Working Group on 11/16/21, https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/PES/AAFM-PES-Cobenefits-11162021.pdf. [*hereinafter* Soil Health Co-benefits].

b) Framing for Vermont's Global Warming Solutions Act

The GWSA sets targets to reduce Vermont state emissions by not less than 26% from 2005 levels by 2025, not less than 40% from 1990 levels by 2030, and not less than 80% from 1990 levels by 2050.[4] Pursuant to these requirements, the GWSA created the Vermont Climate Council (VCC) to identify, analyze, and evaluate strategies and programs to reduce emissions pursuant to these targets,[5] and to identify means to accurately measure the state's emissions and progress towards meeting the targets.[6]

Agriculture and forestry play significant roles in Vermont's state economy and will therefore play an important role in the state's Vermont Climate Action Plan.[7] To understand the current initiatives in the agriculture and forestry sectors and to develop policies in line with the state's climate targets, the GWSA also directed the VCC to establish an Agriculture and Ecosystem's Subcommittee (hereafter referred to as the Subcommittee) to "focus on the role Vermont's natural and working lands play in carbon sequestration and storage, climate adaptation, and ecosystem and community resilience."[8] The outcome of this report can be used to support the Subcommittee's inquiry.

Two separate reports published in 2021 support the state in assessing how it will meet the goals of the GWSA; *A Carbon Budget for Vermont: Task 2 in Support of the Development of Vermont's Climate Action Plan* (Carbon Budget),[9] and the *Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2017* (Emissions Inventory).[10] The EX-Ante Carbon-balance tool (EX-Act) designed by the Food and Agriculture Organization[11] was used to calculate emissions for the Carbon Budget with a focus on Agriculture, Forestry and Other Land Uses (AFOLU) and the Emissions Inventory used the State Inventory and Projection Tool (SIT) designed by the US Environmental Protection Agency (EPA) that looks at all sectors but has historically been limited in the scope of analysis for AFOLU.[12]

[4] 10 V.S.A. § 578 (a)(1-3).
[5] 10 V.S.A. § 591 (b)(1).
[6] 10 V.S.A. § 591 (b)(3).
[7] *See* Soil Health Co-benefits.
[8] 10 V.S.A. § 591 (c)(4).
[9] Dr. Gillian Galford, Dr. Heather Darby, Frederick Hall, & Dr. Alexandra Kosiba, "A Carbon Budget for Vermont: Task 2 in Support of the Development of Vermont's Climate Action Plan," (2021), https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Carbon%20Budget%20for%20Vermont%20Sept%202021.pdf. [*hereinafter* Carbon Budget].
[10] Air Quality and Climate Division, "Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2017," (2021), https://dec.vermont.gov/sites/dec/files/aqc/climate-change/documents/_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2017_Final.pdf. [*hereinafter* Emissions Inventory].
[11] Food and Agriculture Organization of the United Nations, "Economic and Policy Analysis of Climate Change: EX-ACT TOOL," (2022), https://www.fao.org/in-action/epic/ex-act-tool/overview/en/. [*hereinafter* EX-ACT].
[12] United States Environmental Protection Agency, "State Inventory and Projection Tool," (last updated 12/6/21), https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool. [*hereinafter* SIT].

The Emissions Inventory to meet the GWSA targets will quantify emissions reductions across all sectors. The Carbon Budget was developed specifically to account for all emissions and sinks, estimating the extent to which carbon sequestration in natural and working lands balances GHG emissions from all fossil fuels. Thus, the Emissions Inventory essentially estimates gross emissions, while the Carbon Budget estimates net emissions for the Agriculture, Forestry, and Other Land Use (AFOLU) sector. The Carbon Budget report focuses on the AFOLU sector as instructed by the VCC, because the sector "provides opportunities to reduce emissions and boost carbon sequestration."[13]Although the Carbon Budget is not yet used to account for emissions reductions towards the GWSA, it was conducted in a manner that it could be used for the AFOLU sector should the Climate Council decide to use it.

The measurements provided by the SIT tool does not accurately portray emissions levels of Vermont's agriculture sector, and the Subcommittee found that SIT "cannot quantify specific land use practices and farmer management in quantifying emissions reduction and sequestration," and that SIT "decouples the analysis of agricultural emissions from agricultural and forestry sinks and prevents a net accounting of agriculture and forestry emissions per the 2019 IPCC Update."[14]

In contrast, the Carbon Budget used the EX-Act tool because it "better accounts for emissions related to land use practices common to Vermont, including cover cropping, reduced tillage, and no-tillage,"[15] but the authors acknowledge the estimates, in their current form, can not be disaggregated by field or by season [16] (*see footnote[17]*). EX-ACT can be calibrated with Tier III data (IPCC definition), which would be field level data from the region for future efforts.[18]

Dr. Gillian Galford, a lead author of the Carbon Budget, explained that EX-Act could be a promising option for a Vermont whole-farm inventory and calibrating the EX-Act tool to regional or subregional data is possible. As Ex-ACT has already been used for the Carbon Budget, it could easily be leveraged for farm scale estimates if relevant Tier III data is available.

Importantly, the level of rigor of all bookkeeping approaches are essentially the same-- the differences come from which land uses are included, and if Tier 1, 2 or 3 data is used. Dr.

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[13] *See* Carbon Budget at 8.
[14] Vermont Agriculture and Ecosystems Subcommittee, "Resolution recommending amendments to the State of Vermont GreenHouse Gas Inventory protocol," bullets 12 & 13 (9/10/2021). [*hereinafter* Ag & Eco Subcommittee].
[15] *See* Carbon Budget at 8.
[16] *See* Carbon Budget at 10.
[17] "EX-ACT is well-suited to assessing project activities at a range of scales. While the tool works best at project level, given that only one dominant soil and climate type can be considered at a time, it can nonetheless be easily up-scaled to regional and national scales. In such cases, sensitivity analyses of soil and climate conditions or separate EX-ACT analyses conducted by region may be undertaken to supplement the usual appraisal process and ensure precise results." *See* Uwe Grewer, Louis Bockel, Laure-Sophie Schiettecatte & Martial Bernoux, "Ex-Ante Carbon-balance Tool (EX_ACT): Quick Guidance," *Food and Agriculture Organization of the United Nations*, 8 (2017), https://www.fao.org/fileadmin/templates/ex_act/pdf/EX-ACT_quick_guidance.pdf.
[18] Gillian Galford, personal correspondence, (7/18/22).

Galford added that DNDC is very already well calibrated to the Northeast, originating from New Hampshire, and could be used. Further parameterization to use a tool which is specifically calibrated for Vermont would be a large research effort without much change in the model estimates, and therefore may not be worth the investment of resources.[19]

With these shortcomings in mind, the Subcommittee issued a set of recommendations to VCC to pursue technical research on "the shortcomings of each of the tools currently used by the State of Vermont to quantify greenhouse gas emissions (SIT, Ex-act, and LEAP) for evaluating changes in the agriculture sector," and "recommend options for creating a more accurate and nuanced quantification approach to enable agriculture in Vermont to meet the goals of the GWSA, including consideration of process-based models developed for North America, such as DNDC."[20] This report informs this need from the Subcommittee, in part, and could be used to inform the work of VT PES working group.

2) Methods

a) Systematic Literature Review

Tools were chosen for review based on direction from Vermont Agency of Agriculture Food and Markets personnel and from the recommendations of the PES Working Group and the Subcommittee. Researchers compiled sources relevant for each tool, including user manuals, peer-reviewed studies, and websites.

b) Interviews

To gain a deeper understanding of each tool's effectiveness the researchers conducted personal interviews with experts familiar with the tools. Interviews were conducted by either phone call, zoom meeting, or email exchange. Dr. Gillian Galford, Research Associate Professor with UVM, provided information for background on EX-Act and the Carbon Budget by email. Judson Peck, Agricultural Water Quality Program Coordinator with VAAFM, provided general project background also by email. Online interviews were conducted with the following experts: Roland Kröbel for Holos; Clarence Rotz for Integrated Farm System Management (IFSM); Horacio Aguirre for the Farm Level Environmental Assessment of Organic Dairy Systems in the U.S.; Ward Smith for DNDC; Michaela Aschbacher for COOL Farm Tool; Jaehak Jeong and Phillip Gassman for EPIC/APEX; Stephen Del Grosso for DAYCENT, and Adam Chambers for COMET. Interviewees were asked the following questions (or variations):

1. To start, please tell me about how you got into this work. What is your background and why do you do what you do?

[19] *Id.*
[20] Ag & Eco Subcommittee at bullet (a).

2. Which Whole Farm Ecosystem Services Assessment are you familiar with?

3. We are doing a SWOT analysis to summarize key aspects of each model in our report. a) In your opinion, what are the strengths of this model? b) What are the weaknesses? c) What is not accounted for or included in it? d) What do you see as opportunities for impact and use in the world, currently or in the future? e) Are there any external threats or challenges that will limit its use, impact, or effectiveness in the world?

4. What would need to change for this tool to be used for policy, regulations, or incentive programs, like a PES system?

5. What is the future for the models? Will there be new additions/expansion of capabilities? When was the last time it was updated? Who updates them and how often?

6. How would the model be calibrated in the face of climate change?

7. What needs to be adjusted or calibrated to use the tool in Vermont?

8. Can the model accommodate diversified farms?

c) <u>Information Presentation: SWOT Analysis, Table</u>

Following the research process, information from the various sources for each tool were compiled and analyzed using a SWOT analysis to identify specific Strengths, Weaknesses, Opportunities, and Threats. This information is summarized for each individual tool and is also presented in tables attached to this report for comparison. Relevant information regarding GHG accounting tools that was not appropriate for the SWOT analysis or tables is included in Section 3 of this report.

3) Overview of both general and larger context items and functionality to evaluate for each tool

There are many factors to consider when comparing different GHG accounting tools, though not all were appropriate to include in the SWOT analysis or Tables. This section includes several important factors to consider, both pertaining to selecting tools themselves and for the wider context in which they will be used in Vermont.

a) <u>Steps for Selecting a Tool</u>

Tool comparisons are complex and, in some ways, not fully possible because different tools frame emissions according to different criteria (i.e., some use product type as a distinguishing factor while others use land uses).[21] Previous studies have compared greenhouse gas accounting tools, though there is not yet a comparison that focuses on this specific selection of tools or on the Vermont context.

Still, some studies offer useful frameworks for comparing and selecting tools, such as one process defined by the World Bank and the Food and Agriculture Organization of the United Nations (FAO). This process recommends progressing from predefined criteria (aim, geographical zone/application, available data, time, and skills) before then identifying 1) land use activity being measured, 2) land use changes to be accounted for, and 3) greenhouse gases, carbon pools, and leakage.[22]

To use these steps to choose a model for the objectives outlined in this report, the predefined criteria include an aim of accurately assessing whole-farm emissions for a PES system and to inform policies intended to meet Vermont's required emissions reductions within the timeframe laid out in GWSA. To fulfill the remaining predefined criteria, policy makers will need to determine 1) what data is available and what resources can be allocated to collecting more data, 2) what skills are currently available for using the tools, and 3) and what resources can be allocated to hiring and training personnel. Following that, policy makers can determine specifics of agriculture and forestry land uses to measure, what land use changes need to be considered, and which specific outputs are being sought.

b) Tool Characteristics

i) Life Cycle Analysis

Life cycle analysis (LCA) is used to evaluate the full impact of a product on the environment (in this case, the impact of agriculture on GHG emissions).[23] This methodology therefore includes emissions measurements for all on-farm activities, as well as those linked to products sourced off-farm (fertilizer, feed, etc.).[24]

Typically, LCAs consist of five steps:

1) Goal and scope definition, which includes defining the system boundary and functional unit of analysis

[21] Vincent Colomb et al., "Review of GHG Calculators in Agriculture and Forestry Sectors," UN Food and Agriculture Organization, 8 (June 2012), https://www.fao.org/fileadmin/templates/ex_act/pdf/Review_existingGHGtool_GB.pdf.
[22] Anass Toudert et al., "Carbon Accounting Tools for Sustainable Land Management," World Bank Group, 122 (2018), https://openknowledge.worldbank.org/handle/10986/31062.
[23] Sustainable Agriculture Research & Education Program, "Life Cycle Assessment (LCA)," (n.d.; accessed 1/24/22), https://sarep.ucdavis.edu/are/energy/lca.
[24] *Id.*

2) Life cycle inventory (LCI), which includes identification and quantification of all inputs at each stage of the life cycle included within the system boundary

3) Impact analysis

4) Interpretation of impact analysis.[25]

Because LCAs provide a holistic method for inventorying emissions produced by different farm management systems, emission inventory tools that incorporate a LCA will more accurately inform farm decisions for reducing greenhouse gases. However, calculations for upstream emissions are vulnerable to large uncertainties.[26] Section 5 includes further discussion of integrating emissions modelling tools, such as those reviewed in this report, into a LCA.

ii) Inclusion of Forests, Wetlands, Land-Use Change

Forests and wetlands are integrated with farmland in Vermont's working landscape.[27] Many farms include wooded areas, both as part of the property but also as part of the business and management of the farm.[28] Many farm GHG inventories conducted in Vermont will be incomplete if these areas are left out of the estimate calculations.

As the Subcommittee identified as a key shortcoming for SIT,[29] many greenhouse gas quantification tools include these land areas but have decoupled them from farmland in their calculations. Additionally, the Carbon Budget noted that this complicates net-balance calculations on farms that establish or remove tree cover on their farms—for example, areas that have been reforested along riparian areas could then be included in the inventory for forest land resulting in the carbon sequestered in that area not being credit/attributed to the farm's carbon inventory.[30]

iii) Follows Intergovernmental Panel on Climate Change (IPCC) guidelines

As part of the research process for this report, tools were evaluated to ensure that they comply with methodology described by the IPCC, which delineates tool scope into three tiers. Tier 1 covers very large-scale approaches and uses average emission factors for "large eco-regions of the world," while Tier 2 uses data specific to a state or region, and Tier 3 uses a very

[25] *Id.*
[26] A. Del Prado, P. Crosson, J.E. Oleson, & C.A. Rotz, "Whole-farm models to quantify greenhouse gas emissions and their potential use for linking climate change mitigation and adaptation in temperate grassland ruminant-based farming systems," *Animal*, (2013), https://www.researchgate.net/publication/259433671_Whole-farm_models_to_quantify_greenhouse_gas_emissions_and_their_potential_use_for_linking_climate_change_mitigation_and_adaptation_in_temperate_grassland_ruminant-based_farming_systems. [*hereinafter* Del Prado et al.].
[27] *See* Soil Health Co-Benefits
[28] *Id.*
[29] Ag & Eco Subcommittee bullets (12) &(13).
[30] *See* Carbon Budget at 58.

detailed approach at the farm or field scale that usually includes biophysical modelling.[31] Calculators should be chosen to accurately reflect their intended use.

iv) Model Type

This report includes both process-based models and bookkeeping approaches to estimating greenhouse gas emissions, but prioritizes the latter option. Bookkeeping models are based on emissions factors[32], and use research based standard emissions values for different management and ecosystem characteristics alongside information of a farm's production and management records to estimate emissions.[33] On the other hand, process-based biogeochemical models use mechanistic equations based on historical research to simulate growth, nutrient, water, soil, and GHG dynamics.[34] Process based models can "offer significant advantages in predicting the effects of global change as compared to purely statistical or rule-based models based on previously collected data."[35]

(1) Time-Step

Both model types can calculate information according to different time-steps, or the temporal intervals between output values.[36] The relevant time-steps for this report are yearly and daily, where a yearly time-step will quantify factors based on a single value representing an entire year, but a daily time-step can capture greater variations by quantifying values for a factor for each day.[37] It should be noted that time steps can be any length of time and monthly time-steps are used in other common modelling tools, like CENTURY.[38]

All else being equal, a short time step will give more accurate results because of the model's great capability "to represent interactions between the farmer, climate and management," though modelling on a shorter time step can also require more extensive data collection.[39]

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[31] Vincent Colomb et al., "Selection of appropriate calculators for landscape scale greenhouse gas assessment for agriculture and forestry," *Environmental Research Letters,* 3 (2013), https://iopscience.iop.org/article/10.1088/1748-9326/8/1/015029.
[32] *Defined as* "a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant." US EPA, "Basic Information of Air Emissions Factors and Quantification," *Air Emissions Factors and Quantification*, (updated 1/4/22; accessed 3/2/22), https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification.
[33] *See* Del Prado et al.
[34] *Id.*
[35] K. Cuddington et al., "Process-based models are required to manage ecological systems in a changing world," (2013), https://esajournals.onlinelibrary.wiley.com/doi/10.1890/ES12-00178.1.
[36] SORTIE-ND, "Timesteps and run length," (accessed 3/11/22), http://www.sortie-nd.org/help/manuals/help/using/timesteps.html#:~:text=The%20basic%20time%20unit%20in,listed%20in%20the%20parameter%20file.
[37] *Id.*
[38] Natural Resource Ecology Laboratory, "The CENTURY Model," *Colorado State University*, (accessed 3/11/22), https://www.cgd.ucar.edu/vemap/abstracts/CENTURY.html#:~:text=The%20CENTURY%20model%20is%20a,agricultural%20lands%2C%20forests%20and%20savannas.
[39] *See* Del Prado et al.

c) Larger Context Considerations

i) Available Data

The Carbon Budget noted that poor data is a key limitation on Vermont greenhouse accounting, especially for calculations related to AFOLU.[40] Additionally, much of the literature and information gathered from interviews indicate that the degree of model uncertainty—especially for the most sophisticated tools like DNDC—depends on the comprehensiveness and accuracy of data available for inputs (*see footnote*[41]) making data availability a principal determinant of tool effectiveness.

However, collecting comprehensive data for Vermont's agriculture sector would be a large research effort.[42] Policy makers will need to consider whether the state has sufficient resources for such an undertaking, and the models for some tools that are already calibrated for regional conditions–like Holos and IFSM–may not be significantly improved to warrant the expense of data collection.[43]

A more feasible option may be to use sources of existing data to fill information gaps. As put forward by the authors of the Carbon Budget, "a database could be created from existing nutrient management plans required for farms; such a database would centralize information on fertilizer rates and types and provide precise information about manure management at different rates and could be regularly updated. Additionally, tracking changes in land use requires knowing both the prior and the current land use for the same location."[44] Other useful pre-existing data sources include the United States Department of Agriculture (USDA) National Land Cover Database, the US Forest Service Forest Inventory and Analysis, databases from the USDA National Agricultural Statistics Service (NASS), the IPCC, and, to the extent necessary, fossil fuel emissions from the VT GHG Inventory.[45]

Additionally, consideration should be given to data that does not need to be collected or that should not be included because of potential redundancy in a statewide inventory. For example, farm emissions from fossil fuels are already documented as transportation emissions and energy consumption in the VT GHG Inventory,[46] so a cross-sectoral inventory that includes fossil fuel emission in whole-farm measurements could be double-counted if those same emissions are also included in the transportation and energy inventory.

[40] *See* Carbon Budget at 6.
[41] *For specific instances of this assertion, look to analyses for DNDC and Holos.*
[42] Gillian Galford, notes from personal correspondence by email, (2/8/22).
[43] *Id.*
[44] *See* Carbon Budget at 6.
[45] *Id.* At 11.
[46] *Id.*

ii) Consider cross-over between GWSA, PES and other uses

The policy objectives and the research for this project align strongly with both those of the Vermont Payment for Ecosystem Services and Soil Health Working Group (PES working group) and of the Subcommittee. Among the options that the PES working group has considered is a possible PES system funded through trading carbon credits on a market.[47] A tool chosen to inventory GHGs on Vermont farms could allow the time and resource investment by both the VCC and PES working group if it were applicable to both groups' objectives. Therefore, the VCC could benefit from selecting a tool that was considered credible for market participation or applicable to quantification of other ecosystem services in a PES system.

Furthermore, many of the tools are already used by other organizations whose scope could overlap with Vermont's stakeholder goals. For example, the (USDA) used APEX for its Conservation Effects Assessment Project (CEAP) and Soil and Water Assessment Tool (SWAT), the USDA Natural Resources Conservation Services (NRCS), uses COMET-Planner for conservation practice planning, and Ben & Jerry's—a major customer for Vermont Dairy Farmers—selected COMET-farm to measure emissions to monitor progress towards their carbon goals.[48] Any tool that is used by an organization whose objectives align with the Subcommittee or PES Working Group should be especially considered because of the potential to share resources and have measurements that are directly aligned between organizations. Consistent quantification approaches across these groups would also ensure consistent messaging and information to farmers

iii) Socio-economic factors

Using the results of a whole-farm emissions inventory to drive change in the agriculture sector will need to take an inter-connected response to design policies that reduce emissions without causing other harms to state residents.[49] Though emissions are a primary factor driving climate change, it is important to avoid "carbon tunnel vision" and to consider emission reduction strategies within the context of their social and economic implications.[50] Several of the tools included in this report—IFSM, Holos, and APEX—include economic analyses for projected management scenarios, which can be a helpful aid when designing policy to meet state emission reduction requirements. As well, many of the tools include assessment of ecosystem services other than climate mitigation.

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[47] VT Agency of Agriculture, Food, and Markets, "Soil Conservation Practice and Payment for Ecosystem Services Working Group Report," 6, (January 15, 2020), https://legislature.vermont.gov/assets/Legislative-Reports/Soil-Conservation-Practice-and-PES-Working-Group-Report-01152020.pdf
[48] USDA NRCS, "Commonly Used NRCS Tools - COMET Farm," (n.d.), https://comet-farm.com/. "*COMET is the official greenhouse gas quantification tool of USDA*."; USDA, "Climate Smart Conservation Partnership Serves Two Scoops of On-Farm Solutions," (2017),https://www.usda.gov/media/blog/2016/12/21/climate-smart-conservation-partnership-serves-two-scoops-farm-solutions. ; *For other examples see report tables in appendix.*
[49] Tina Nybo Jensen, "Expert Opinion: Avoiding Carbon Tunnel Vision," *Environmental Analyst | Global*, (2021), https://environment-analyst.com/global/107463/expert-opinion-avoiding-carbon-tunnel-vision. [*hereinafter* Jensen].
[50] *Id.*

4) Modelling Tools[51]

To support Vermont policy makers' goals, this report evaluates eight tools that could be applied for modelling greenhouse gas emissions at the whole-farm level; COMET-Farm, COMET-Planner, COOL-Farm, DayCent, DNDC, EPIC & APEX, Holos, and IFSM. EPIC and APEX are both considered as one tool within this report because of their close similarities and applications (and because APEX is based on EPIC). Although COMET-Farm and COMET-Planner use the same GHG estimation methodology and COMET-Planner is based on COMET-Farm, these two have different applications and will be considered separately. It should be noted that DayCent is a component of COMET-Farm but is not the only methodology Comet-Farm incorporates into its estimations. This section offers a brief high-level summary of these eight tools, with more detailed information framed as a SWOT analysis pertaining to each tool represented in the appendix.

a) Emissions modelled

All of the tools model carbon dioxide (CO_2) and nitrous oxide (N_2O), simulate carbon sequestration, and include measurements for manure management (note that DNDC has a supplementary Manure-DNDC tool that produces more comprehensive manure management simulations than the primary DNDC tool). Holos, DayCent, IFSM, COOL-Farm, COMET-Farm, and COMET-Planner also model methane (CH_4). All tools measure enteric emissions (*see footnote*[52] *for definition*) except DayCent, Comet-Planner, and EPIC/APEX, though DNDC only measures enteric emissions through the Manure-DNDC model. EPIC/APEX can simulate emissions for forested areas and wetlands, while DNDC can do so if used alongside supplementary Forest-DNDC and Wetland-DNDC tools. IFSM can model forest emissions as land use change. DayCent and IFSM do not estimate GHG emissions for forested areas.

Holos, IFSM, and EPIC/APEX include upstream (*see footnote*[53] *for definition*) emissions calculations for pesticides, while COOL-Farm only partially models pesticide impacts. All models except DNDC measure on-farm and/or off-farm emissions associated with fuel and energy use.

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[51] *All references and citations for information to this section can be found in corresponding appendices.*
[52] *For a definition of Enteric Methane, see* US EPA, "AP-42, CH 14.4: Enteric Fermentation - Greenhouse Gases," 14.4-1, https://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s04.pdf.; "Enteric fermentation is fermentation that takes place in the digestive systems of animals. In particular, ruminant animals (cattle, buffalo, sheep, goats, and camels) have a large "fore-stomach," or rumen, within which microbial fermentation breaks down food into soluble products that can be utilized by the animal."
[53] *For an example of Upstream Emissions, see* World Resources Institute & World Business Council for Sustainable Development, "Greenhouse Gas Protocol," 10 (n.d.), https://ghgprotocol.org/sites/default/files/standards/GHG%20Protocol%20Agricultural%20Guidance%20%28April%2026%29_0.pdf.; "Upstream companies include manufacturers of farm inputs, such as seeds, fertilizers, herbicides, and pesticides."

b) Accuracy

Three of the tools evaluated—Holos, COMET-Planner, and COOL-Farm--rely on emission factors to calculate expected emissions for various farm-management practices and systems. These tools are often user friendly but produce outputs that are less accurate and site-specific than the process-based models that are represented by the other four included in this report (DayCent, IFSM, DNDC, and EPIC/APEX). COMET-Farm's methodology is a combination of emissions factors and process based modelling, and thus COMET-Farm uses both process-based measurements and emissions factors.

Other accuracy considerations include the models' time-step, where both Holos and COOL-farm model emissions use a yearly-time step that produces less accurate outputs than the daily time-step employed by the other six tools, as well as the IPCC tier methodology—COMET-Farm and COMET-Planner use tier 1, 2, and 3 methodology; Cool-Farm uses tiers 1 and 2; IFSM uses tier 2; Holos uses tiers 2 and 3; and DayCent, DNDC, and EPIC/APEX use tier 3.

c) Opportunities

Many of the opportunities described for each tool regard ongoing research and development. Some tools also have other features that can be used for other policy initiatives outside of modelling emissions. For example, all tools reviewed, except COOL-Farm and older Holos versions (*see footnote*[54]), offer some outputs regarding water quality (Holos' newest version will also include these calculations for water). COOL-Farm is the only tool reviewed that models water footprint and biodiversity. Holos, IFSM, and EPIC/APEX also include economic analyses for management changes modeled by the tool.

Many of the tools are used in other programs or by other organizations that may work synergistically with Vermont policy, such as the USDA's use of EPIC/APEX for CEAP and SWAT.

All tools except DNDC and DayCent are free and easy to download from the internet. For DNDC, free access may be contingent on contacting the University of New Hampshire and signing a waiver to use the tool for strictly research purposes. DayCent is free and available upon request from the University of Colorado. Agriculture and Agri-Food Canada have supported Holos for the past two decades. DayCent, EPIC/APEX, Comet-Farm, Comet-Planner, Holos and IFSM receive robust support from their host organizations.

d) Threats

[54] *Distinction of Holos versions specified because of the recency of the newest versions release; at the time of writing, ongoing applications of Holos measurements that have not yet transitioned to the new version—and all but the most recent existing research—will be based on older Holos versions.*

The most common threats for tools are based on a tool's difficulty, where the more sophisticated models–DNDC, DayCent, EPIC/APEX, IFSM–require users to have advanced training. This threatens the tool's applicability for modelling Vermont farm emissions because there may be a shortage of qualified technicians to use the models.

Additionally, the outputs of any model are only as good as the inputs and will need regular updates to reflect current management. In this way, models are threatened by the burden of data entry, poor data quality, inaccessible data, or limited resources for compiling sufficient data.

5) Example Applications

This section will give an overview of three examples of greenhouse gas modelling tools being used to measure emissions, and then describe each in detail.

The Farm Level Environmental Assessment of Organic Dairy Systems in the U.S (FLEAODS) was developed by Dr. Horacio Aguirre-Villegas at the University of Wisconsin and is currently utilized by Organic Valley. FLEAODS carefully coordinates IFSM outputs alongside several other information sources (for example, other available software and emissions factors and USDA databases for weather and crop yields calibrated to different areas of the U.S.) through Excel to create a comprehensive LCA for organic dairy farms. Though this LCA does not currently include the range of land uses needed to be applicable in Vermont (notably, it does not incorporate forest land), ongoing developments aim to expand the range of land uses. This LCA is a good example for developing a framework to measure whole farm emissions that addresses the limitations of using a single modelling tool, but which requires robust technical assistance to use effectively.

The Logiag Carbon Project aims to help farmers determine management changes to reduce emissions. Logiag couples strong reliance on Holos based calculations with supplementary information sources, like government geospatial data. An important characteristic of Logiag's approach is its reliance on historical farm data to create a baseline against which farmers can make comparative emissions reductions. While this approach is not highly accurate and does not yield results that can be comparable between different farms, it shows a strategy for modelling emissions that can be done by farmers with minimal or no technical assistance and may identify practices or fields where the biggest impact on GHG emissions may take place.

The He Waka Eke Noa Primary Sector Climate Action Partnership does not include any of the tools reviewed in this report. However, it does demonstrate a strategy designed by farmer initiative. It relies on farmers' self-reporting in a regulatory context to generate estimates of on-farm emissions. Currently, He Waka Eke Noa is pursuing a strategy that uses a central calculator (still to be designed) that all eligible farmers can record data into and that would, ideally, allow other emissions tracking tools to seamlessly import their data.

A) FLEAODS[55]

This LCA aims to calculate whole-farm emissions for organic dairy farms in the U.S. Although the current model only considers emissions for dairy production—as well as crops linked to those production systems— the research team of Dr. Aguirre-Villegas also evaluated beef systems and ongoing research aims to expand the farm boundaries to include emissions from other landscape features like forested areas and wetlands.

The LCA combines various tools and models into a framework within Excel to relate different farm practices and characteristics to emissions related to farm activities. Emissions from manure collection, manure storage, and related activities are calculated from IFSM. Simapro LCA software[56] is used for emissions produced from on-farm energy and other materials (e.g., fertilizers, feed supplements, etc.) and IPCC emission factors are used for N_2O emissions from manure deposition on grassland.

All data are regionally calibrated by leveraging data sources like crop yields from USDA records, meteorological data for rainfall and other weather factors, and regional energy supply information for electrical and energy use. To accommodate the various tools, the LCA includes methods linked to IPCC Tiers 1, 2, and 3 (for example, CH_4 emissions from manure storage are for Tier 3, but manure N_2O emissions are for Tier 1).

Developing and calibrating the LCA required extensive data collection from real farms within each region, which Dr. Aguirre-Villegas says is a great strength of this LCA over others. As with other LCAs, FLEAODS is vulnerable to inaccuracies due to the various assumptions and data sets used to generate emissions calculations. Furthermore, because FLEAODS is an amalgamation of multiple models that each use their own data sets and assumptions, the different models may include different calculations for emissions depending on the methodology that model applies.

While this LCA is already parameterized for different regions—including the northeast United States—using the model for the purpose of calculating emissions for a Vermont PES program or to inform policy for the GWSA would require modifying the data for state-specific variations like differences in forages, climatic conditions, and soil types. Fortuitously for developing Vermont policy, this LCA already includes outputs—such as nutrient runoff—that are relevant to ecosystem services other than carbon storage, and ongoing research aims to expand those calculations to include other environmental factors. Furthermore, the LCA places a greater emphasis on carbon sequestration than other models.

The Organic Valley LCA is more approachable than some of the more complex process-based tools and could be more readily employed across Vermont's agriculture sector. Still, the

[55] All following information is from Horacio Aguirre-Villegas, Personal Interview, March 7, 2022, except where otherwise noted. *Also see* UVM Extension Northwest Crops and Soils Program, "Dairy Webinar Series: Green House Gas Emissions on Organic Dairy," (March 2, 2022), https://www.youtube.com/watch?v=3Thg-uatTg8.
[56] Simapro, "LCA Software for Informed Change-makers," (accessed 3/7/22), https://simapro.com/.

range of data input required and the cruciality of using the most accurate data available means that users should receive some level of training.

B) Logiag Carbon Project[57]

The Logiag Carbon Project is a framework for estimating whole farm emissions using the Holos tool and aims to help farms strategize methods to reduce emissions but does not consist of an environmental assessment or lifecycle analysis. The framework does not incorporate all outputs that can be generated by Holos. It also supplements Holos with some calculations that the software does not cover and adapts some parameters to be more site-specific. Logiag also leverages data—mostly related to provincial regulatory elements of production and phosphorus reduction—from its register of thousands of Quebec farms that employ Logiag as an agronomy service provider, as well as government data for information regarding bodies of water and woodlands.

The estimated values resulting from the framework include Scope 1 emissions, like those from crops and soil, fossil fuel combustion, livestock, land-use change, and tree planting of windbreaks (but not forestland); Scope 2 emissions like imported electricity; and Scope 3 emissions like those from mineral fertilizer and herbicide production.[58] Logiag recognizes that their inventory does not include all Scope 3 emissions from upstream and downstream activities like transportation of goods to and off farm. Logiag's inventory and greenhouse gas declarations follow international standards, and mathematical calculations are based on the 2006 IPCC guidance.[59]

The Carbon Project estimates emissions by first setting a boundary to differentiate between emissions within the farm and those outside of the farm. Farm and field boundaries relevant to the analysis correspond to areas declared in each farm's Agro-Environmental Fertilizer Plan (AEFP), indicating that Logiag's inventory does not account for non-crop land.[60] Logiag then creates a baseline with three years of historical farm data. It estimates emissions for CO_2, N_2O, and CH_4, which are calculated into units of CO_2 equivalents (CO_2e) to facilitate comparisons. By

[57] All following information is from Logiag, "Farm Greenhouse Gas Emissions Inventory: For Jacques Nault's Farm," (Juse 2021), https://docs.google.com/document/d/1bn13Da21yK7br2nwVMjFpIsU7Escmd3THFf-pn4Xoao/edit, [*hereinafter* Logiag], except where otherwise noted.
[58] For a definition of emissions scopes, *See:* Carbon Trust, "Briefing: What are Scope 3 emissions?," (2022), https://www.carbontrust.com/resources/briefing-what-are-scope-3-emissions. "Scope *Greenhouse gas emissions are categorised into three groups or 'Scopes' by the most widely-used international accounting tool, the Greenhouse Gas (GHG) Protocol. Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.*
[59] *See* Logiag; "*To produce the inventory, Logiag referred to the Greenhouse Gas Protocol (GHG Protocol Agricultural Guidance) and ISO 14064-1 for guiding principles on the quantification and disclosure of GHG sources and sinks. Both guides present a normative framework for measuring, managing, and reporting a farm's GHG emissions."*
[60] *Id.*; *also see* "[chapter Q-2, r. 26 Environment Quality Act: Agricultural Operations Regulation Division IV (3)] *and* [chapter Q-2, r. 26 Environment Quality Act: Agricultural Operations Regulation Division IV (22)] *for a definition of Quebec 'Agro-environmental fertilization plan.'*

combining farm management information and data from the sources listed above into Holos, Logiag can correlate estimated emission levels with changes in farm management by comparing against the baseline calculated from historical data.

Logiag's analysis is currently only applicable to Canadian farms because of its reliance on Holos; however, the summary for Holos included in this report indicates that the tool could be calibrated to Vermont conditions.[61] Alternatively, a similar tool could be substituted in and used within the same framework.

C) He Waka Eke Noa Primary Sector Climate Action Partnership

The circumstances surrounding the He Waka Eke Noa Primary Sector Climate Action Partnership share many similarities with those of the Vermont farming community and the PES Working Group. The partnership is a collaboration between Maori, New Zealand government, and industry leaders to reduce agricultural greenhouse gas emissions,[62] and is currently undertaking its second year of a five-year initiative developed in response to the government's proposal to meet legislative emissions reduction requirements by pricing agricultural greenhouse gas emissions through the New Zealand Emissions Trading Scheme (ETS).[63]

The collaborators issued a proposal to the government in October 2019 for the groups to work together to design an alternative to the government proposed solution that is "practical and cost-effective system for reducing emissions at the farm level by 2025."[64] Some primary aims of the partners are to include carbon-sequestration within the pricing system—which is currently excluded from the ETS—and to measure CH_4 separately.[65]

Some key milestones that the collaboration plans to accomplish include a) by the end of 2021, having 25% of farms know their annual emissions and 25% developing plans to measure and manage emissions, b) presenting a carbon pricing system to ministers in April 2022, c) having 100% of farms completed emissions calculations by the end of 2022, d) completing a pilot project to test a system for farm level accounting and reporting by the end of 2023, and e) having all farms maintain a written plan to measure and manage greenhouse gas emissions, and f) launch a market ready on-farm pricing system.[66]

[61] Roland Kröbel personal interview, January 27, 2022. [*hereinafter* Kröbel Interview].
[62] He Waka Eke Noa Primary Sector Climate Action Partnership, "About," (accessed 3/7/22), https://hewakaekenoa.nz/about/. [*hereinafter* About He Waka Eke Noa].
[63] Dairy NZ, "He Waka Eke Noa," (accessed 3/7/22), https://www.dairynz.co.nz/environment/climate-change/he-waka-eke-noa/.
[64] *See* About He Waka Eke Noa.
[65] *Id.*
[66] He Waka Eke Noa Primary Sector Climate Action Partnership, "Our Work: The Five-year Programme," (accessed 3/7/22), https://hewakaekenoa.nz/our-work/#sec-programme.

The collaborators' proposed options so far include a farm-level tax and a processor-level hybrid tax.[67] The farm-level tax is based on net emissions, with rewards for sequestration and lower emissions costs for farmers that took early action.[68] The processor-level hybrid tax emissions are calculated for the meat, milk, and fertiliser processing stages. The cost of this tax is passed on to farmers by processors, who may offer farmers emissions management contracts to incentivize select management strategies that sequester carbon or reduce emissions.[69] While early action farmers are not rewarded here, overall administrative costs are lower than the farm-level tax.[70]

He Waka Eke Noa currently supports the farm-level tax as the best option. A critical component in this program design is a central calculator for on-farm emissions that all eligible farmers and growers can capture and record data into[71] that would, ideally, allow an easy pathway for current emissions tracking tools to import data.[72] He Waka Eke Noa has reviewed available farm-level modelling tools that farmers could use to perform their own calculations,[73] but the central calculator has not yet been developed.[74] It is important to note that as a part of program design, on-farm audits would only take place when reported emissions are outside of normal ranges.[75] He Waka Eke Noa is currently deliberating between a simple calculation option that recognizes farms for a range of farm management improvements that result in reductions calculated according to industry averages, or a detailed method that costs more but also captures emissions from adopting on-farm efficiencies.[76]

The initial design of He Waka Eke Noa does not include all possible emissions sinks and sources.[77] For instance, the proposed program design is not currently considering wetlands as carbon sinks because of their complexity, but plans to do so in the future.[78] Soil carbon sequestration is also "unlikely to be recognized within the first stages of implementation" because the collaborators recognize more research is needed first.[79] Energy use, because it is

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67 He Waka Eke Noa Primary Sector Climate Action Partnership, "He Waka Eke Noa Agricultural Emissions Pricing Options," *Consultation Document*, (February 2022), https://www.dairynz.co.nz/media/5795066/consultation-document_final.pdf. [*hereinafter* Pricing Options].
68 *Id.* at 5.
69 *Id.*
70 *Id.* at 5-6.
71 *Id.* at 18.
72 *Id.*
73 Phil Journeaux, Louis Batley, & Erica van Reenan, "Review of Models Calculating Farm Level GHG Emissions #2: Prepared for He Waka Eke Noa," *AgFirst*, (May 2021), https://hewakaekenoa.nz/wp-content/uploads/2021/05/Review-of-Models-Calculating-Farm-Level-GHG-Emissions-2-June-2021.pdf. [*hereinafter* Models Review].
74 *See* Pricing Options at 16.
75 *Id.* at 18.
76 *Id.*
77 He Waka Eke Noa Primary Sector Climate Action Partnership, "He Waka Eke Noa Frequently Asked Questions," (accessed 3/7/22), https://hewakaekenoa.nz/faqs/.
78 *Id.*
79 *Id.*

already accounted for in New Zealand's ETS, will also not be covered in the emission budget.[80] However, forest land will likely be included as a carbon sink but will be attributed to a different emissions inventory because of New Zealand regulations like the Zero-Carbon Act, which stipulates that CH_4 emissions cannot be offset directly through forest sequestration.[81]

6) Conclusion

The tools listed in this report present several options for measuring whole-farm emissions in Vermont. The information here can aid the Subcommittee and the PES Working Group to select a tool or suite of tools that is best suited to meeting their objectives.

Based on the framework outlined by the World Bank and FAO, and on the information presented regarding the tools, the primary factors that Vermont policymakers will need to outline before moving forward are 1) data availability and resources to allocate for data collection, 2) the level of output accuracy that is being sought (i.e. the degree of uncertainty the groups are willing to accept), or that is necessary to fulfill GWSA requirements, and 3) the amount of resources that can be allocated to hiring and training technicians, respective to the different skill levels needed to use each tool effectively. In a scenario of ample resources it would be possible to collect extensive data and deploy trained technicians to generate highly accurate simulations with tools like DNDC or EPIC/APEX. In another scenario of low resources, Vermont could use bookkeeping models with emissions factors and rely on farmers to input their own data using tools like Holos, Cool-Farm, COMET-Farm, or COMET-Planner. IFSM requires medium level of data input and technician training (*see footnote*[82]).

Additionally, determinations need to be made regarding the whole range of objectives that a chosen tool will need to fulfill. If the tool is to be used solely for measuring whole-farm emissions with no other policy applications it can then be assessed strictly on its own merits for modelling emissions. As shown by the LCA used by Organic Valley, and by Logiag's Carbon Project, a tool that has some information gaps can still be used effectively alongside supplementary data sources.

But if the tool were to be used in a PES system, then other factors—like other services measured by the tool, or what tool is regarded as credible by possible 'buyers' participating in a PES program—become more important. Choosing a model that aligns with another organization or program is likely to be an important factor outside of PES applications, both for perceived

[80] *Id.*
[81] *See* Models Review at 24.
[82] Clarence Rotz related during his interview that, in his experience as a highly trained user of the IFSM, a whole farm data collection will take about 4 hours.

credibility but also for resource efficiency and to reduce the amount of times individual farms must gather information for, take measurements for, or enter data into different models.

Whichever tool is chosen, policy surrounding the tool's use should avoid "carbon tunnel vision" by considering emission reduction strategies within the context of their environmental, social, and economic implications,[83] and "an integrated approach is needed to avoid pollution swapping (i.e. leaching) when selecting among GHG mitigation options."[84] Similarly, a Vermont program that quantifies farm-level greenhouse gas emissions could also use the built-in economic analyses present in several of the tools to evaluate social and economic impacts, though a tool without such analyses could incorporate social and economic factors through policy design.

[83] *See* Jensen.
[84] *See* Del Prado et al.

APPENDICES

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[85] *Data for this chart was taken from user manuals describing inputs for these tools. We tried to frame inputs as the model developers framed them, but in some cases we consolidated similar groups of inputs for brevity.*
[86] *Data in these charts for the eight tools reviewed in this report can be cited to sources listed in the report. However, Ex-Act and SIT (marked with an asterisk), were covered less extensively in the report. Information in this chart can be found in the following sources.*

Ex-Act
1. E. Milne, et a., “Methods for the quantification of emissions at the landscape level for developing countries in smallholder contexts: CCAFS Report No. 9,” CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS), (2012).
https://cgspace.cgiar.org/bitstream/handle/10568/24835/CCAFS9%20WEB%20FINAL.pdf
2. Louis Bockel, Uwe Grewer, Chlo Fernandez, & Martial Bernoux , "EX-ACT User Manual: Estimating and Targeting Greenhouse Gas Mitigation in Agriculture," FAO, IRD, & World Bank, (n.d.).
3. https://documents1.worldbank.org/curated/en/611041487662158062/pdf/112809-WP-EX-ACTUserManuaFinal-WB-FAO-IRD-PUBLIC.pdf

SIT
1. CF International, “Assessment of the Comparability of Greenhouse Gas and Black Carbon Emissions Inventories in North America,” Commission for Environmental Cooperation, (2012).
http://www.cec.org/files/documents/publications/10938-assessment-comparability-greenhouse-gas-and-black-carbon-emissions-inventories-en.pdf
2. ICF International, “User’s Guide for Estimating Carbon Dioxide, Methane, and Nitrous Oxide Emissions from Agriculture Using the State Inventory Tool,” State Energy and Environment Program, U.S. Environmental Protection Agency, (2022)

APPENDIX 1: Holos[87]

Summary

The Holos tool is a bookkeeping model that uses IPCC Tier 2 emissions factors to produce estimates of CO_2, N_2O, and CH_4 emissions based on management practices for individual farms[88] on a yearly time-step.[89] The version currently available on the government website is 4.0, released March 16, 2022, which aims to "provide a deeper look at practices that affect soil carbon levels"[90] and will include a new shelterbelt and anaerobic digestion component alongside a number of updates to existing components.[91] Agriculture and Agri-Food Canada have provided robust support for Holos for the last two decades.

Holos was designed to help project the outcomes of different management scenarios to inform management decisions and is intended as an exploratory, rather than accounting, tool.[92] However, the outputs from the tool are still accurate inventories (depending on the accuracy of inputs) and can be used for accounting emissions.[93]

To generate an emissions inventory with Holos, users select from amongst various scenarios that best describe an individual farm before adding more detailed information specific to their unique circumstances.[94] The program is intentionally designed to simplify the accounting process by using default values as much as possible to calculate results, but while also allowing the opportunity to override those default values to generate more accurate outcomes.[95] The Holos 3.0.6 model includes options for 18 major crops (now "greatly expanded" in version 4.0) with detailed estimates for beef, dairy, swine, and poultry, and less detailed estimates for other

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https://www.epa.gov/system/files/documents/2022-03/ag-module-users-guide.pdf

3. ICF International, "User's Guide for Estimating Emissions and Sinks From Land Use, Land-Use Change, and Forestry Using the State Inventory Tool," State Energy and Environment Program, U.S. Environmental Protection Agency, (2022).

[87] Government of Canada, "Holos Software Program," (01-24-2020), https://agriculture.canada.ca/en/agricultural-science-and-innovation/agricultural-research-results/holos-software-program. [*hereinafter* Agri-Food Canada].

[88] *Id.*

[89] Karen A.Beauchemin et al., "Life cycle assessment of greenhouse gas emissions from beef production in western Canada: A case study," *Agricultural Systems,* (2010), https://www.sciencedirect.com/science/article/abs/pii/S0308521X10000387?via%3Dihub.

[90] Piper Whelan, "Researchers see producer feedback on environmental assessment software," *Canadian Cattlemen: The Beef Magazine,* (July 8, 2020), https://www.canadiancattlemen.ca/features/researchers-seek-producer-feedback-on-environmental-assessment-software/. *Also see* Kröbel et al., "The Canadian whole-farm Model Holos-development of the new Version 4," *American Geophysical Union* (2020), https://ui.adsabs.harvard.edu/abs/2020AGUFMGC0990007K/abstract. [*hereinafter*

[91] *See* Agri-Food Canada.

[92] Kathryn Slebodnik et al., "Holos as a Greenhouse Gas Estimation Tool for Animal Agriculture Northern Utah," (2020), https://projects.sare.org/wp-content/uploads/Holos-Factsheet_Version4.pdf. [*hereinafter* Slebodnik et al.].

[93] *See* Kröbel interview.

[94] Roland Kröbel et al., "Demonstrations and Testing of the Improved Shelterbelt Component in the Holos Model," *Environmental Science* (2020), https://www.frontiersin.org/articles/10.3389/fenvs.2020.00149/full. [*hereinafter* Kröbel et al.]

[95] *See* Kröbel interview.

livestock.[96] Estimates for emissions are calculated from this management information using algorithms based on IPCC methods but modified for Canadian conditions.[97] Summary calculations for net outcomes are expressed as CO2 equivalent (CO2eq),[98] though reports that distinguish between CH4, NO2, and CO2 can also be generated.[99]

Holos is based on IPCC tier 2 and 3 methodologies, with modifications for Canadian conditions.[100] Carbon storage calculations were based on the "methodology developed for the National Inventory Report, the Canadian Agriculture Monitoring Accounting and Reporting System (CanAG-MARS)," which includes calculations for changes in tillage practice, use of fallow, percentage of perennial crops, and areas of permanent cover.[101] In Version 4.0, the Holos model features both the IPCC Tier 2 carbon model (based on the widely used CENTURY model) and also the Introductory Carbon Balance model (ICBM) to permit a more detailed assessment of soil carbon change due to crop rotation and residue management practices.[102]

Strengths

The two great strengths of the Holos software are 1) its adaptability, as it was designed to accommodate user modification, and 2) its simplicity, which allows the software to be used beyond research to also inform decisions by farmers and policymakers.[103]

Although the N_2O algorithms for Holos are calibrated to Canadian conditions and so do not accurately reflect those of Vermont, Holos "can be applied to regions with similar climates in the United States … by manually overriding soil and climatic parameters when used with a proper understanding of its design and limitations."[104]

The livestock calculations (enteric CH_4) and carbon change estimates can be readily utilized, emission factors for manure storage and application, however, might require verification, despite their temperature adjustment.

Holos aims to calculate emissions based on the farm as an integrated whole, rather than the sum of its parts, and its projections take into account the interactions of different

[96] *Id.*
[97] *See* Slebodnik et al.
[98] *Id.*
[99] *See* Kröbel interview.
[100] E.J. McGeough et al., "Life-cycle assessment of greenhouse gas emissions from dairy production in Easter Canada: A case study," *Journal of Diary Science*, (2012), https://www.sciencedirect.com/science/article/pii/S0022030212005322.
[101] *Id.*, at 19.
[102] *Id.*.; Also *see* Alister K. Metherell, Laura A. Harding, C. Vernon Cole, & William J. Parton, "CENTURY Soil Organic Matter Model Environment," (1993), https://www2.nrel.colostate.edu/projects/century/MANUAL/html_manual/man96.html.; *Also see* FAO, "Measuring and modelling soil carbon stocks and stock changes in livestock production systems," 17 (2019), https://www.fao.org/3/ca2933en/CA2933EN.pdf.
[103] *Id.*
[104] *See* Slebodnik et al.

components.[105] Emissions that are calculated for farm activities include manufacture and transport for farm inputs like fertilizer and herbicide.[106] Carbon storage for lineal tree plantings, farm shelterbelts, and riparian plantings is included in the estimates.[107]

Holos projects estimates for individual farms and may not be applicable for a state- or sector-wide assessment.[108]

Weaknesses

Holos is not intended to inventory emissions, and instead is better suited for strategizing management to reduce emissions.[109] Although lineal tree plantings, etc., are included in the estimates, the model "does not calculate storage or emissions from managed, long-established or natural woodlots."[110] Although the Holos algorithms can be manually overridden to better reflect Vermont, doing so requires a sophisticated understanding of the software's design and limitations.[111]

Though the program's ease-of-use is counted above as a strength, the model's corresponding simplicity also threatens the tool's accuracy if the appropriate data is not overridden for greater specificity.[112] Additionally, although the tool is simple and easy to understand, the actual process of data entry can be time consuming.[113]

Opportunities

Holos is free to download through the Agriculture and Agri-Food Canada website.[114] The tool can also be used to measure Life-Cycle Assessments and to establish baseline measurements for tracking progress of reducing farm emissions, as was done by Logiag (*see footnote*[115]).

Because the tool is widely usable it can be applied to many decision-making processes beyond the farm, including policy or education.[116]

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[105] *See* Kröbel et al.
[106] Agriculture and Agri-Food Canada, "Holos: A tool to estimate and reduce GHGs from farms," 10 (2008), https://publications.gc.ca/collections/collection_2009/agr/A52-136-2008E.pdf. [*hereinafter* Holos Guidebook].
[107] *Id.*, at 44.
[108] Aditi Maheshwari, "Automating and Analyzing Whole-Farm Carbon Models," *Graduate Thesis: Utah State University*, 12 (2020), https://digitalcommons.usu.edu/etd/7869/.
[109] *See* Slebodnik et al.
[110] *See* Holos Guidebook at 44.
[111] *See* Slebodnik et al.
[112] *See* Kröbel interview.
[113] Vincent Colomb et al., "Review of GHG Calculators in Agriculture and Forestry Sectors," UN Food and Agriculture Organization, 8 (June 2012), https://www.fao.org/fileadmin/templates/ex_act/pdf/Review_existingGHGtool_GB.pdf.
[114] *See* Agri-Food Canada.; Training *Documents can be found at:* https://drive.google.com/file/d/13A1j-Vjrlz6HshXjIt1EQlL-D9pIEHer/view.
[115] Logiag, "Farm Greenhouse Gas Emissions Inventory: For Jacques Nault's Farm," (Juse 2021), https://docs.google.com/document/d/1bn13Da21yK7br2nwVMjFpIsU7Escmd3THFf-pn4Xoao/edit.
[116] *See* Kröbel interview.

Additionally, the adaptability of the software means that it can be applied to uses other than emissions modelling, such as for PES programs.[117] Adapting the tool in this way will require utilizing what it already outputs into something that represents an ecosystem service—for example, Holos' current design to calculate N_2O emissions is based on a factor of how much nitrate is leached, which could be transferred into a water quality assessment.[118]

Threats

Manually overriding the program to better reflect Vermont requires a sophisticated understanding of the software that will be difficult for many individuals.[119] Holos is updated every few years to reflect new data or technological advancements, which will pose a particular problem if the program needs to be overridden again to reflect Vermont's conditions.[120]

Although older versions of the model were free to download, and although Holos version 4.0's calculation core will be released open source, the interface of Holos version 4.0 cannot be released as open source due to having proprietary software until the tool's programmers can design it as an open-source HTML interface.[121]

[117] *Id.*
[118] *Id.*
[119] *See* Slebodnik et al.
[120] *Id.*
[121] *See* Kröbel interview.

APPENDIX 2: DayCent

Summary

"DAYCENT is the daily time-step version of the CENTURY biogeochemical model."[122] Simulation time steps for soil process are simulated on a daily or finer scale, vegetation production daily, and management practices daily. DayCent uses the IPCC Tier 3 three approach for calculating greenhouse gas (GHG) emissions which "use complex simulation models or extension monitoring systems."[123] Based on weather, field management practices, vegetation, soil type, fuel use, and other parameters, it estimates GHG emissions (N_2O, NO_X, N_2, CO_2), carbon sequestration, leaching of NO_3, and net primary production, and other ecosystem parameters.[124,125] It is used as the underlying model for COMET-Farm.[126] See Figure 1 at the end of this document for a diagram of the model flow.

Strengths

DayCent is a process-based model and has some life cycle analysis assessments (biofuel).[127] DayCent is a widely recognized tool and components of it are included in Comet-Farm. It is currently used by the US EPA, USDA, and Colorado State University to create a national N_2O inventory for U.S. agricultural soils. These results are different from the IPCC's U.S. emissions inventory as the IPCC uses emissions factors (as opposed to process-based modeling).[128] For example, IPCC assumes nitrogen applied in one year is used that year while DayCent can account for legacy nitrogen from previous applications.[129] Following IPCC guidelines, DayCent models indirect N_2O emissions. DayCent has been accessible for decades and compared to other models in peer-reviewed journal publications.

DayCent is well supported and has had recent improvements including moving from weekly vegetation production and monthly management practice time-steps to daily. It has been

[122] Colorado State University. (2012 DayCent. https://www2.nrel.colostate.edu/projects/daycent/
[123] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[124] Colorado State University. (2012). DayCent. https://www2.nrel.colostate.edu/projects/daycent/
[125] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[126] Steenworth, K.L., X. Barker, M. Carlson, K. Killian, M. Easter, A. Awan, L. Thompson, S. Williams, and K. Paustian (2016) Developing COMET-Farm and the DayCent Model for California Specialty Crops. Abstract. American Geophysical Union, Fall Meeting.
[127] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[128] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[129] *Id.*

adapted to include specialty crops for use in California.[130] Furthermore, DayCent is calibrated with field research,[131] but this field research is limited by its locations and may not be representative of all growing conditions in the U.S.

DayCent is able to simulate average crop production by state with reasonable accuracy for many common crops.[132] Inputs for DayCent are easy to acquire and DayCent can be used to estimate impacts on GHG emission of changing cropping systems at the regional scale (e.g. corn ethanol to miscanthus or switchgrass)[133] or management practices (e.g. conventional tillage to no-till).[134] "Results from DAYCENT suggest that conversion to no tillage at the national scale could mitigate 20% of USA agricultural emission or 1.5% of total USA emission of greenhouse gases."[135] DayCent can model outcomes based on climate change e.g. extreme weather scenarios and increased levels of CO_2 in the atmosphere.[136]

Weaknesses

In order to generate site-specific estimates, a high level of user data input is required and some amount of transparency is lost with more complex calculations.[137] Due to the robustness of DayCent, programming expertise and sophisticated software is required to keep the model relevant and current.[138] DayCent is better calibrated for growing conditions in some states than others. Although DayCent does not calculate GHG from fuel emissions on farms, or emissions from manufacture and transportation of farm inputs, model outputs can be combined with other methods to perform life cycle assessments (e.g., Adler P.R, Del Grosso, S.J and Parton, W.J. 2007. Life cycle assessment of net greenhouse gas flux for bioenergy cropping systems. Ecological Applications. 17(3):675–691).

Although DayCent, "simulates decomposition and nutrient mineralization of plant litter and soil organic matter, plant growth and senescence, and soil water and temperature fluxes," it

[130] Steenworth, K.L., X. Barker, M. Carlson, K. Killian, M. Easter, A. Awan, L. Thompson, S. Williams, and K. Paustian (2016) Developing COMET-Farm and the DayCent Model for California Specialty Crops. Abstract. American Geophysical Union, Fall Meeting.
[131] Del Grosso, Stephen. Personal communication. February 15, 2022.
[132] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[133] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[134] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[135] *Id.*
[136] Del Grosso, Stephen. Personal communication. February 15, 2022.
[137] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[138] *Id.*

is not a whole farm assessment. Although it is similar to DNDC (models use similar data sets, require similar inputs, and compute similar results (which reduced uncertainties)), DayCent does not explicitly represent soil microbial dynamics It does not quantify GHG emissions from manure storage.[139] Like most models, DayCent makes certain assumptions on data inputs (bulk density, C:N of vegetation, NH_4 confinement to top 15 cm, etc.).[140] Although DayCent can account for tile drainage when modeling NO_3 leaching, its assumptions are one dimensional meaning it does not factor topography or hydrology and therefore erosion into the analysis.[141] DayCent is designed to run simulations for major crops and grassland[142] and therefore may not be well suited for more diversified livestock operations or rice production.[143]

Opportunities

DayCent can be used to model the impact of different cropping systems or management practices on GHG emissions, reductions, or sequestration.[144] DayCent has been adapted to include elements of PH REdox EQuilibrium (PHREEQC; in C language) to form DayCent-Chem, a tool that models nutrient cycling (including NO_3, NH_4, and SO_4 loss into surface water) and GHGs in forests.[145] This model that utilizes DayCent for forests could be modified to be included in a Vermont whole-farm GHG and water quality assessment. Although DayCent defaults to nitrogen analysis for water quality, it does have a phosphorus sub-model. However, the phosphorus sub-model could benefit from more internal assessment to minimize uncertainties and incorporation of a hydrological model.

DayCent could be calibrated to better fit Vermont growing conditions. DayCent developers are working to increase experimental sites, compare model ensembles, add a soil microbial component, and create a global version (limited by global data sets e.g. weather and to major crops like rice, wheat, corn, cotton, rangeland, etc.). [146] DayCent development is subject to

[139] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[140] *Id.*
[141] Del Grosso, Stephen. Personal communication. February 15, 2022.
[142] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[143] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[144] Del Grosso, Stephen, D. Ojima, W. Parton, E., M. Heistemann, B. DeAngelo, S. Rose. (2009). Global scale DAYCENT model analysis of greenhouse gas emissions and mitigation strategies for cropped soils. Global and Planetary Change. Vol (67) 1–2, 44-50. doi: 10.1016/j.gloplacha.2008.12.006
[145] Hartman, Melanie, J. Baron, D. Clow. E. Creed, C. Driscoll, et. al. (2009). DayCent-Chem Simulations of Ecological and Biogeochemical Processes of Eight Mountain Ecosystems in the United States. Scientific Investigations Report 2009–5150. U.S. Department of the Interior, U.S. Geological Survey, in cooperation with Natural Resource Ecology Laboratory, Colorado State University.
[146] Del Grosso, Stephen. Personal communication. February 15, 2022.

funding and stakeholder priorities, one of which is quantifying GHG, water quality, and habitat benefits for a whole-system approach.[147]

Threats

As with all models, output is only as good as the input and algorithms. Algorithms and parameters are always subject to some internal and structural uncertainties.[148] However, rigorous uncertainty analysis of DayCent results have been performed (e.g., Gurung, R.B., Ogle, S.M., Breidt, F.J., Parton, W.J., Del Grosso, S.J., Zhang, Y., Hartman, M.D., Williams, S.A. and Venterea, R.T., 2021. Modeling nitrous oxide mitigation potential of enhanced efficiency nitrogen fertilizers from agricultural systems. Science of The Total Environment, p.149342, doi.org/10.1016/j.scitotenv.2021.149342).. A potential threat to DayCent is misuse of the tool by by changing model inputs or parameter values to achieve desired results (conflict of interest) or misunderstanding of the outputs especially if sufficient attention is not paid to uncertainties.

When DayCent output is compared to field data, N_2O estimations are often within 33% of measured values and NO_3 leaching is within 30% (compared to 50% underestimation with IPCC emissions factors methodology and a difference of factoring leaching of N from fixation).[149] It can model mean annual N_2O estimations reasonably well, but not daily fluxes.[150] DayCent, like all models could benefit from more robust field data sets that are long-term and capture different growing conditions. For example, national N_2O monitoring stations would not only benefit modeling software, it would also inform our current state of emissions. DayCent has limitations on the specificity of certain field management practices. For example, although it can model impacts of nitrification inhibitors, it cannot fully account for type and placement of fertilizers.[151] DayCent, like other government or university funded projects, may be subject to high competition for experienced staff and future model development and application could be limited by resource availability.

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[147] *Id.*
[148] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0
[149] Del Grosso, Stephen, A. Mosier, W. Parton, and D. Ojima. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. Soil & Tillage Research 83 (9-24). doi:10.1016/j.still.2005.02.007.
[150] *Id.*
[151] Del Grosso, Stephen. S. Davis, and P. Adler. (2012). DayCent Model Simulations for Estimating Soil Carbon Dynamics and Greenhouse Gas Fluxes from Agricultural Production Systems. Managing Agricultural Greenhouse Gases. doi:10.1016/B978-0-12-386897-8.00014-0

SECTION 4
Modeling to Estimate Soil Carbon Dynamics and Greenhouse Gas Flux

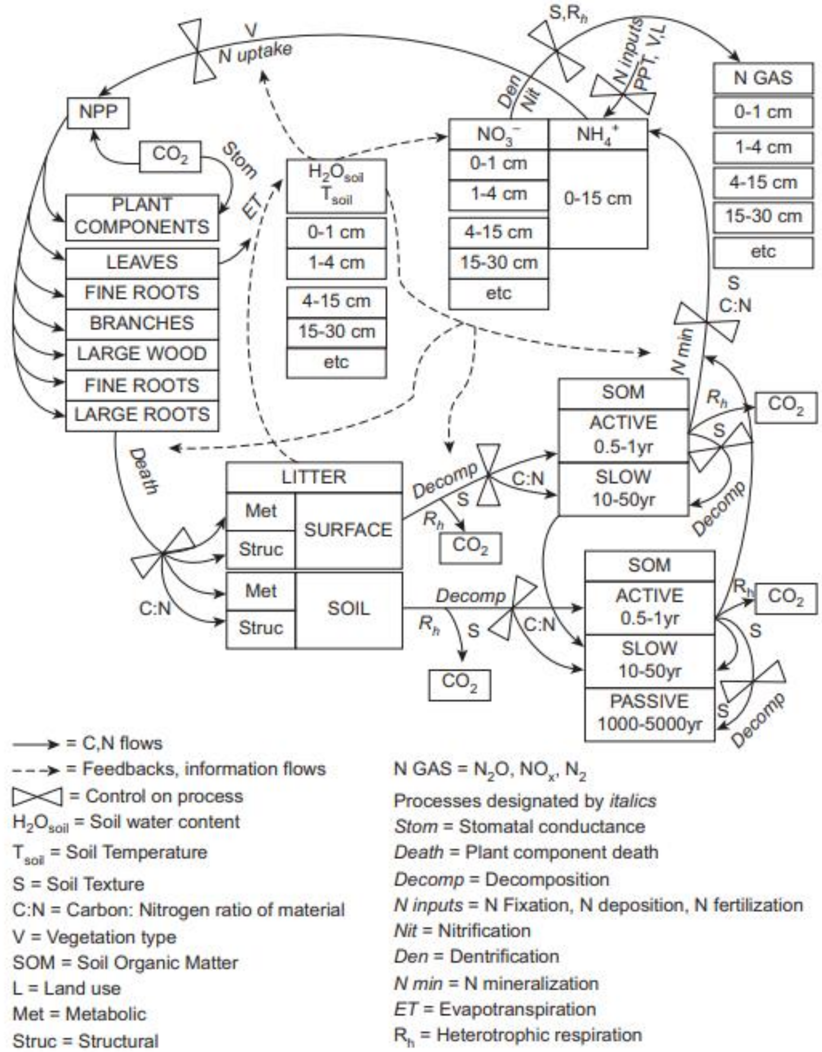

FIGURE 14.1
DayCent model flow diagram.

APPENDIX 3: COMET-Farm

Summary

COMET-Farm estimates a carbon footprint and allows users to evaluate different options to sequester carbon or reduce greenhouse gas (GHG) emissions. It was developed by the United States Department of Agriculture (USDA), Natural Resources Conservation Services (NRCS), and Colorado State University. It was developed in response to 1605 B Title of the Energy Policy Act to allow voluntary reporting of GHGs.[152] COMET-Farm uses methods from Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory.[153]

COMET-Farm has four accounting activities: Field (cropland, pasture, range, orchard/vineyard management practices), livestock (animal number, size, breed, and manure management information), agroforestry (tree type, dbh/age, and stocking rate), and forestry (tree stand type and management). [154] The platform allows users to see changes in GHG based on changes in field management practices (cover crops, reduced tillage, more precise fertilizer applications). COMET-Energy is also available, as a separate tool, to assess fuel related emission reductions.

Strengths

COMET-Farm estimates are based on GHG inventory methods that are defined by independent expert science working groups and are vetted in a public review process by other expert scientists and government agencies which make it one of the most transparent and scientifically robust GHG inventory systems of its kind.[155] There are approximately 25 different models within COMET-Farm.[156] In other words, estimate methodology aligns with national inventory methods and is endorsed by the USDA.[157]

COMET-Farm is actively supported, maintained, and updated. Overall, COMET-Farm can estimate GHG emissions for a diversity of operations and farm management systems.[158] In 2021, new features were added to account for more specific irrigation information, the nutrient balance calculator was updated to display total amount of nitrogen applied, and other upgrades were made to improve performance.[159] In 2022, a carbon farm planning curriculum is anticipated

[152] Paustian, Keith and H. Nagle. Personal communication. March 25, 2022.
[153] Eve, Marlen, D. Pape, M. Flugge. R. Steele, D. Man, M. Riley-Girlbert, and S. Biggar (eds). 2014. Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. USDA Technical Bulletin 1939.
[154] H. Nagle. Personal communication. July 16, 2022.
[155] Paustian, Keith and H. Nagle. Personal communication. March 25, 2022.
[156] Paustian, Keith. Personal communication. July 16, 2022.
[157] Chambers, Adam. Personal communication. March 23, 2022.
[158] *Id.*
[159] Comet. 2021. "Welcome to COMET-Farm™." Info. http://comet-farm.com/News

to be released.[160] COMET-Farm uses spatially explicit data which means climate and soil conditions are locally based. COMET-Farm creates baseline and projected 10-year[161] estimates based on the information the user inputs which means it is flexible to create estimates for select fields or the whole-farm.[162]

In addition to the Field Module, COMET-Farm also has a livestock module and an optional energy tool (COMET-Energy).[163] The advanced Livestock Module allows for users to input information on feed and supplement characteristics. The energy tool requires on-farm energy use information in addition to the Field Module. COMET-Farm incorporates different land management systems (annual and perennial crops, pasture, range, and agroforestry).[164] Sugaring and wood harvested for heating in fireplaces is accounted for in the biogenic cycle land use section.[165]

Each module relies on scientifically verified methods of calculation. DayCent is used to calculate soil carbon estimates in the Field Module (as of July 2022), though later in 2022, it will be updated to the 30cm DayCent Model and account for both soil carbon and N2O changes.[166] The Livestock Module's estimates are based on USDA and models and university research.[167] This tool allows for robust, historical data entry which increases its prediction accuracy. Although this may be a data entry burden, the user interface is streamlined to allow users to copy management practices to subsequent years and/or fields.

Data entered is not used, shared, or viewed by the USDA.[168]

Reports are created to show differences between the baseline practices and up to ten alternative[169] scenarios. Reports display information in tables and graphs. Results are exportable into a spreadsheet.[170]

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[160] Chambers, Adam. Personal communication. March 23, 2022.
[161] Paustian, Keith, M. Easter, K. Brown, A. Chambers, M. Eve, A. Huber, E. Marx, M Layer, M. Stermer, B. Sutton, A Swan, C. Toureene, S. Verlayudhan, and S. Williams. 2018. Field- and farm-scale assessment of soil greenhouse gas mitigation using COMET-Farm. Precision Conservation: Geospatial Techniques for Agricultural and Natural Resources Conservation, Vol. 59 https://doi.org/10.2134/agronmonogr59.c16
[162] Comet. 2021. "Why should I use COMET-Farm." Dashboard pop-up. http://comet-farm.com/#
[163] Comet. 2021. "What information do I need?" Dashboard pop-up. http://comet-farm.com/#
[164] Paustian, Keith, M. Easter, K. Brown, A. Chambers, M. Eve, A. Huber, E. Marx, M Layer, M. Stermer, B. Sutton, A Swan, C. Toureene, S. Verlayudhan, and S. Williams. 2018. Field- and farm-scale assessment of soil greenhouse gas mitigation using COMET-Farm. Precision Conservation: Geospatial Techniques for Agricultural and Natural Resources Conservation, Vol. 59 https://doi.org/10.2134/agronmonogr59.c16
[165] Chambers, Adam. Personal communication. March 23, 2022.
[166] H. Nagle. Personal communication. July 16, 2022.
[167] Comet. 2021. "How are my results calculated?" Dashboard pop-up. http://comet-farm.com/#
[168] USDA. N.d. Privacy Policy. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/about/?cid=nrcsdev11_000885
[169] H. Nagle. Personal communication. July 16, 2022
[170] Allen, Gemma. 2020. Multiple Perceptions of Soil Health: A Transdisciplinary Collaborative Study of two Contrasting Grain Farms in Columbia County, NY. Division of Social Studies. Bard Undergraduate Senior Projects. https://digitalcommons.bard.edu/cgi/viewcontent.cgi?article=1029&context=senproj_s2020

COMET-Farm is widely utilized tool. For example, as of 2021, COMET-Farm had 12,834[171] visitors and is listed as a tool in the National Oceanic and Atmospheric Administration's (NOAA) U.S. Climate Resilience Toolkit[172], Cornell University's Climate Smart Farming,[173] and the Land Trust Alliance.[174]

Weaknesses

COMET-Farm is limited in cover crop options i.e., it does not create estimates for complex cover crop mixes.[175] COMET-Farm does not account for GHG from machinery or vehicular use as that is included in other sections of the National GHG inventory.[176] As with other models there are uncertainties when it comes to time and weather, and uncertainties are not quantified.[177] GHG emissions under climate change are not estimated as there is too much uncertainty of attributing influence to climate change and not weather variability.[178] COMET-Farm may refer to IPCC defaults to create estimates for diversified farm scenarios (farming operations with non-dominant crops).[179] Like most other models, COMET-Farm does not quantify co-benefits and ancillary benefits.[180] Consistent with USDA GHG flux methodology, COMET-Farm supports, but does not perform life cycle analysis.[181]

Opportunities

COMET-Farm could be expanded to include modules on water quality, soil health, or biodiversity. Including an economics module may expand COMET-Farm's decision-making support tool applications to include carbon markets or payment for ecosystem services programs.[182] Furthermore, COMET-Farm could be expanded to include more comprehensive life

[171] Miller, Spencer 2017.COMET-Farm™: Conservation Calculation. USDA blog. https://www.usda.gov/media/blog/2013/08/21/comet-farmtm-conservation-calculation
[172] U.S. Climate Resilience Toolkit. 20s1.COMET-Farm. NOAA. https://toolkit.climate.gov/tool/comet-farm
[173] Cornell University. 2022.COMET-Farm GHG Accounting Tool. Climate Smart Farming. http://climatesmartfarming.org/tools/comet-farm/
[174] Land Trust Alliance. 2021.COMET-Farm GHG Accounting Tool. Conservation in a Changing Climate. https://climatechange.lta.org/comet-farm/
[175] Allen, Gemma. 2020. Multiple Perceptions of Soil Health: A Transdisciplinary Collaborative Study of two Contrasting Grain Farms in Columbia County, NY. Division of Social Studies. Bard Undergraduate Senior Projects. https://digitalcommons.bard.edu/cgi/viewcontent.cgi?article=1029&context=senproj_s2020
[176] Chambers, Adam. Personal communication. March 23, 2022.
[177] Chambers, Adam. Personal communication. March 23, 2022.
[178] *Id.*
[179] Paustian, Keith, M. Easter, K. Brown, A. Chambers, M. Eve, A. Huber, E. Marx, M Layer, M. Stermer, B. Sutton, A Swan, C. Toureene, S. Verlayudhan, and S. Williams. 2018. Field- and farm-scale assessment of soil greenhouse gas mitigation using COMET-Farm. Precision Conservation: Geospatial Techniques for Agricultural and Natural Resources Conservation, Vol. 59 https://doi.org/10.2134/agronmonogr59.c16
[180] Chambers, Adam. Personal communication. March 23, 2022.
[181] Eve, Marlen, D. Pape, M. Flugge. R. Steele, D. Man, M. Riley-Girlbert, and S. Biggar (eds). 2014. Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. USDA Technical Bulletin 1939.
[182] Paustian, Keith, M. Easter, K. Brown, A. Chambers, M. Eve, A. Huber, E. Marx, M Layer, M. Stermer, B. Sutton, A Swan, C. Toureene, S. Verlayudhan, and S. Williams. 2018. Field- and farm-scale assessment of soil

cycle analysis. Currently, COMET-Farm does not provide estimates for management systems that utilize precision agriculture.[183] COMET-Planner (uses a fixed baseline) has been adapted for use in the California Healthy Soils Program.[184] More applications of COMET-Farm are upcoming with a CIG grant to estimate benefits of conservation.[185]

<u>Threats</u>

COMET-Farm requires history data entry (crop or pasture management information from as far back as 2000) which can be a data entry burden. As with any model, the quality of output is dependent on the accuracy of input. Also similar to other models, there is a shortage of literature to integrate into the tool.[186] COMET-Farm seems to be well-supported and maintained by the USDA, but nonetheless will need to be updated to reflect changes in management technologies, cropping systems, and climate and calibrated as new data becomes available. There are many users utilizing the tool and this level of use requires more hours of expert involvement and more cloud storage space which adds to the overall cost of supporting COMET-Farm.[187]

greenhouse gas mitigation using COMET-Farm. Precision Conservation: Geospatial Techniques for Agricultural and Natural Resources Conservation, Vol. 59 https://doi.org/10.2134/agronmonogr59.c16

[183] *Id.*

[184] Jabbour, Randa. S. McClelland, & M. Schipanski. 2021. Use of decision-support tools by students to link crop management practices with greenhouse gas emissions: A case study. Nat Sci Educ. doi.org/10.1002/nse2.20063.

[185] Chambers, Adam. Personal communication. March 23, 2022.

[186] Chambers, Adam. Personal communication. March 23, 2022.

[187] *Id.*

APPENDIX 4: COMET-Planner

Summary

COMET-Planner is a web-based conservation planning tool that uses COMET-Farm, utilizes greenhouse gas (GHG) emission and reduction quantification methods from COMET-Farm, and the USDA entity scale inventory methods to produce generalized estimates of GHG impacts based on conservation practice adoption.[188]

Like Comet-Farm, it was developed by Colorado State University and USDA-NRCS. COMET-Planner evaluates five broad categories of NRCS conservation practices: cropland management, grazing lands, cropland to herbaceous cover, woody plantings, and restoration of disturbed lands.[189] It compares these field practices or suites of practices to a fixed baseline.[190]

Strengths

Compared to COMET-Farm, COMET-Planner is a streamlined tool that allows farmers to quickly estimate regionally-averaged GHG emissions and reductions from field-based practices and compare them to a representative baseline management scenario or business as usual. It therefore requires less data than COMET-Farm. Based on changes in field practices, COMET-Planner can quantifu impacts on carbon emissions from improved fuel-efficiency of farm equipment (CPS 372), reduced carbon and N_2O emissions from soils, and soil carbon sequestration.[191] Results from the online tool are downloadable. COMET-Planner provides a quick, low-cost solution to comparing the impact of management practices.

Weaknesses

COMET-Planner is intended for initial conservation planning purposes and generates estimates based on county scale. Therefore, it is not for site-specific analysis.[192] COMET-Farm provides more robust analysis. COMET-Planner provides assessments for field-based practices only and is not a whole-farm assessment.[193] COMET-Planner provides estimated impacts of NRCS conservation practices and therefore is subjected to the bounds of the conservation

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[188] Colorado State University. N.d. Comet-Planner. Brochure. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Brochure.a22406c5.pdf
[189] Amy Swan, Mark Easter, Adam Chambers, Kevin Brown, Stephen A. Williams, Jeff Creque, John Wick, and Keith Paustian. 2020. COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Report_Final.41c0b5e0.pdf
[190] Colorado State University. N.d. Comet-Planner. Brochure. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Brochure.a22406c5.pdf
[191] Amy Swan, Mark Easter, Adam Chambers, Kevin Brown, Stephen A. Williams, Jeff Creque, John Wick, and Keith Paustian. 2020. COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Report_Final.41c0b5e0.pdf
[192] Colorado State University. N.d. Comet-Planner. Brochure. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Brochure.a22406c5.pdf
[193] *Id.*

practice standard (CPS) and not all conservation practices may be listed for VT yet.[194] Thus, COMET-Planner does not provide estimates for all conservation practices farmers may implement. In addition, the streamlined nature of the tool does not allow users to modify assumptions of practices. For example, perennial forage in the strip cropping practice (CPS 585) is not fertilized with nitrogen.[195] COMET-Planner is limited in its ability to quantify the impact of CPS on GHG emissions. It aims to quantify CO_2, N_2O, and CH_4 for specific CPSs, but is not able to calculate N_2O and CH_4 for all practices. COMET-Planner is not a life cycle assessment tool nor does it provide estimates for whole-farm or forestry GHG emissions and reductions,

Opportunities

COMET-Planner could be expanded to quantify impacts from additional management practices, beyond the scope NRCS practices standards, and the impact of management practices on water quality (nitrogen and phosphorus loss). COMET-Planner has been adapted for use in the California Healthy Soils Program, expanded by American Farmland Trust as their Carbon Reduction Potential Evaluation (CaRPE) tool,[196] and will be used by the USDA Climate Smart Commodity grant program.[197] Therefore could serve as a viable tool for Vermont farm field GHG emission and reduction quantification. There is global interest in COMET-Planner and the tool could benefit from calibration to other locations outside the US and explore relationships with supporting institutions and trade partners.[198]

Threats

COMET-Planner is well supported by Colorado State University and NRCS. However, one of its biggest limitations is its narrow scope. COMET-Planner is a general tool and is not designed to be site-specific or quantify GHG emission or reductions outside of its pre-defined conservation practices. The greatest threat to utilizing this tool may be the slow pace of incorporating new technology or cropping methods into its model.

For more information on strengths and limitations of the Comet-Planner: Swan, Amy, S. Williams, K. Brown, A. Chambers, J. Creque, J. Wick, and K. Paustian. (n.d). COMET-Planner Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning. A companion report to the original version of the COMET-Planner tool. https://planner-prod2-dot-comet-201514.appspot.com/static/media/COMET-Planner_Report_V1Legacy.d4f77ec6.pdf

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[194] Chambers, Adam. Personal communication. March 23, 2022.
[195] Comet-Planner. N.d. Comet-Planner homepage. http://comet-planner.com/
[196] Jabbour, Randa. S. McClelland, & M. Schipanski. 2021. Use of decision-support tools by students to link crop management practices with greenhouse gas emissions: A case study. Nat Sci Educ. doi.org/10.1002/nse2.20063.
[197] Chambers, Adam. Personal communication. March 23, 2022.
[198] *Id.*

APPENDIX 5: IFSM (Integrated Farm System Model)

Summary

The Integrated Farm System Model (IFSM) is a simulation program maintained by the USDA that tracks nutrients flows on dairy, beef, grazing, and crop (no livestock) farm operations.[199] Animal feed intake, crop production, fertility management practices, and field operation information is simulated over 25 years of weather data.[200] The IFSM provides a whole-farm nutrient balance for N, P, K, and C, predicts the environmental impact of farm operations on greenhouse gas (GHG) and other important air emissions, water quality, and whole-farm budget.[201]

Strengths

IFSM is one of the most comprehensive, processed based models available. Its simulations are run on daily weather conditions. Weather files include historical or projected future climate for many locations across the U.S. For projected future climate, IFSM utilizes 18 climate files for each location developed using multiple climate models. It predicts "potential nutrient accumulation in the soil and loss to the environment" and takes burning of fossil fuels into account when calculating GHG emissions.[202] The model predictions for phosphorus flow and GHGs are well calibrated for many common crops, production types, field management operations, and manure storage methods.[203,204,205,206] IFSM includes a farm-gate life cycle assessment (LCA)[207] and provides economic analysis. The software is available for free and includes numerous parameter files for farm production systems, farm equipment, and weather.[208] "The IFSM is generic in design and can simulate a wide range of crop rotations, feeding

[199] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.
[200] *Id.*
[201] *Id.*
[202] *Id.*
[203] Ghebremichael, L.T., P.E. Cerosaletti, T.L. Veith, C.A. Rotz, J.M. Hamlett, and W.J. Gburek. (2007). Economic and Phosphorus-Related Effects of Precision Feeding and Forage Management at a Farm Scale. J. Dairy Sci. 90:3700–3715. doi:10.3168/jds.2006-836
[204] *Id.*
[205] Belflower, J.B., J. K. Bernard, D. K. Gattie, D. W. Hancock, L.M. Risee and C. A. Rotz. (2012). A case study of the potential environmental impacts of different dairy production systems in Georgia. Agricultural Systems Volume 108, April 2012, Pages 84-93. doi:10.1016/j.agsy.2012.01.005
[206] Rotz, Alan, M. Corson. D. Chianese, F. Montes, S. Hafner, H. Bonifacio, and C. Cioner. (2018) The Integrated Farm System Model Reference Manual Version 4.4
[207] Asem-Hiablie, S., Battagliese, T., Stackhouse-Lawson, K.R. *et al.* (2019). A life cycle assessment of the environmental impacts of a beef system in the USA. *Int J Life Cycle Assess* **24,** 441–455
[208] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.

strategies, equipment, facilities, and other management options."[209] IFSM accommodates six groups of dairy or beef animal groups.[210]

IFSM simulates farms for 25 years of weather data. From these results, the impact of different weather conditions (e.g. unusually wet, dry, hot, cold) on GHG emissions can be estimated. Simulation options include projecting impact of future weather conditions, subject to climate change, on GHG emissions and nutrient flows. IFSM weather files can be constructed from NOAA recorded data or generated using PRISM.[211] Information from the farm and equipment parameter files can be modified in dialogue boxes through the software program.[212] Additionally, modeling routines can be modified for predicting impacts in other systems like compost management.[213] Reports summarize the results in different formats with different levels of detail.[214] The model is calibrated primarily for the northern U.S., but may be applicable to other regions.

The massive data set provides information for comprehensive studies. One study evaluated the impact of production options on the reduction or elimination of long-term phosphorus accumulation in the soil and increased profit. Another study illustrated the impact of feed choices on reduction of volatile nitrogen loss and increased profit.[215] A third study explores the impact of conventional and organic management practices on soil phosphorus accumulation and erosion. Recent studies have determined national environmental impacts of beef cattle and dairy production for the U.S[216, 217, 218].

IFSM is currently well supported through the USDA. The latest release was in early 2022 and upcoming releases expand the model to include energy produced through solar panels and nutrient flows using nutrient extraction technologies.[219]

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[209] Jégo, Guillaume. C.A. Rotz, G Bélanger, G. F. Tremblay, E. Charbonneau, and D. Pellerin. (2015). Simulating forage crop production in a northern climate with the Integrated Farm System Model. Can. J. Plant Sci. 95: 745757 doi:10.4141/CJPS-2014-375
[210] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.
[211] Rotz, C.A. Personal communication. January 26, 2022.
[212] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.
[213] Bonifacio, H.F., C.A. Rotz, and T. L. Richard. (2017) Process-based model for cattle manure compost windrows: part 1. model description. ASABE. Vol. 60(3): 877-892.
[214] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.
[215] *Id.*
[216] Rotz, C. A., S. Asem-Hiablie, S. Place and G. Thoma. 2019. Environmental footprints of beef cattle production in the United States. Agric. Systems 169:1-13.
[217] Rotz, C.A., R. Stout, A. Leytem, G. Feyereisen, H. Waldrip, G. Thoma, M. Holly, D. Bjorneberg, J. Baker, P. Vadas and P. Kleinman. 2021. Environmental assessment of United States dairy farms. J. Cleaner Prod. (2021), doi: https://doi.org/10.1016/j.jclepro.2021.128153.
[218] Veltman, K., C. A. Rotz, L. Chase, J. Cooper, P. Ingraham, R. C. Izaurralde, C. D. Jones, R. Gaillard, R. A. Larsson, M. Ruark, W. Salas, G. Thoma, and O. Jolliet. 2018. A quantitative assessment of beneficial management practices to reduce carbon and reactive nitrogen footprints and phosphorus losses of dairy farms in the Great Lakes region of the United States. Agric. Systems 166:10-25.
[219] Rotz, C.A. Personal communication. January 26, 2022.

Weaknesses

IFSM provides simulations for dairy, beef, and crop only production systems but does not have capacity to simulate vegetable, other livestock production systems, or diversified farms.[220] The IFSM does not account for field spatial representation.[221] Nor does it include forest management or biodiversity in its simulations.[222]

The model can benefit from field calibration to assure suitable prediction of yield, N-uptake, and crop quality. The model may also be limited in the types of cropping systems it can accept. For example, it cannot fully represent triple-cropping practices.[223] The model does not consider impacts of snow cover which affects soil heat fluctuations.[224] IFSM does not account for pest or weed pressure, but yield could be adjusted to represent crop loss.[225] Although it is primarily designed as a research tool for long-term simulations,[226] it has some educational applications, but is limited in value as a decision support tool[227] i.e. it is not necessarily designed with the intent to inform PES programs and was not intended to be used for regulatory or similar purposes.[228]

IFSM is good for whole-farm (not including forestry) analysis. However, the tool is not suitable for, nor is it designed to conduct, a watershed-level water quality analysis, but it could feed into a watershed water quality analysis model.

Opportunities

The software is available for free to anyone at any time. Download instructions can be found at https://www.ars.usda.gov/northeast-area/up-pa/pswmru/docs/ifsm-download-instructions/.

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[220] Rotz, C.A. (2005). The Integrated Farm System Model: A Tool for Whole Farm Nutrient Management Analysis.
[221] Ghebremichael, L.T., P.E. Cerosaletti, T.L. Veith, C.A. Rotz, J.M. Hamlett, and W.J. Gburek. (2007). Economic and Phosphorus-Related Effects of Precision Feeding and Forage Management at a Farm Scale. J. Dairy Sci. 90:3700–3715. doi:10.3168/jds.2006-836
[222] Rotz, Alan, M. Corson. D. Chianese, F. Montes, S. Hafner, H. Bonifacio, and C. Cioner. (2018) The Integrated Farm System Model Reference Manual Version 4.4
[223] Belflower, J.B., J. K. Bernard, D. K. Gattie, D. W. Hancock, L.M. Risee and C. A. Rotz. (2012). A case study of the potential environmental impacts of different dairy production systems in Georgia. Agricultural Systems Volume 108, April 2012, Pages 84-93. doi:10.1016/j.agsy.2012.01.005
[224] Jégo, Guillaume. C.A. Rotz, G Bélanger, G. F. Tremblay, E. Charbonneau, and D. Pellerin. (2015). Simulating forage crop production in a northern climate with the Integrated Farm System Model. Can. J. Plant Sci. 95: 745757 doi:10.4141/CJPS-2014-375
[225] Rotz, C.A. Personal communication. January 26, 2022.
[226] Jégo, Guillaume. C.A. Rotz, G Bélanger, G. F. Tremblay, E. Charbonneau, and D. Pellerin. (2015). Simulating forage crop production in a northern climate with the Integrated Farm System Model. Can. J. Plant Sci. 95: 745757 doi:10.4141/CJPS-2014-375
[227] Rotz, C.A. (2022). "Software for Evaluating the Environmental Impact of Dairy and Beef Production Systems." Livestock and Poultry Environmental Learning Community.
[228] Rotz, C.A. (n.d.). "The Integrated Farm System Model: Software for Evaluating the Performance, Environmental Impact and Economics of Farming Systems." USDA ARS. https://www.ars.usda.gov/ARSUserFiles/np212/LivestockGRACEnet/IFSM.pdf

Data can be leveraged to conduct more comprehensive studies, and some organizations are offering incentives for participation which will add to its dataset.[229] A well or newly established organization could gather Vermont farm data to create representative Vermont-specific farming operation scenarios. It can be used to assess the impact of different management strategies, like precision feed management, on water quality, whole farm phosphorus budgets, and farm viability.[230] IFSM's intended use is as a research tool and the output focuses on the environmental and economic impacts of a limited range of farming systems. The model could be improved by expanding its ability to generate estimates for different types of production systems and the positive environmental benefits agriculture provides. IFSM could be expanded and applied to PES programs with strong technical assistance as a way to predict changes based on soil type, field management, and weather.

Threats

The model will need to be calibrated as new agricultural technologies emerge. Currently, the model can account for different types of manure injection, but not nitrogen inhibitors.[231] Like most models dealing with complex systems, engaging with it is somewhat knowledge intensive. Utilization of the model requires dedicated staff that have the training and skills to use it correctly along with good understanding of farming practices.[232] Likewise, the availability and quality of data entered into the model depends on farmer time and record-keeping, which may influence the quality of the model's outputs. IFSM is currently maintained and improved by one USDA staff member located at the Pasture Systems and Watershed Management Research Unit in State College, Pennsylvania. IFSM may no longer be supported in the future by the USDA if new staff are not trained or other models developed at other institutions supersede it. Furthermore, keeping IFSM current means updating the model as the software packages it relies on evolves.

For more comprehensive information on IFSM refer to:

Ghebremichael, L.T., P.E. Cerosaletti, T.L. Veith, C.A. Rotz, J.M. Hamlett, and W.J. Gburek. (2007). Economic and Phosphorus-Related Effects of Precision Feeding and Forage Management at a Farm Scale. J. Dairy Sci. 90:3700–3715. doi:10.3168/jds.2006-836

McLean, Andrew. (2012). Modeling Best Management Practices on Representative Farms in Southeastern Pennsylvania Using the Integrated Farm System Model. A Thesis. Pennsylvania State University Graduate School. College of Engineering. https://etda.libraries.psu.edu/files/final_submissions/77

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[229] PASA. (2022). Grazing Dairy Footprint Study. https://pasafarming.org/soil-institute/farm-based-research/grazing-dairy-footprint-study/
[230] Ghebremichael, L.T., P.E. Cerosaletti, T.L. Veith, C.A. Rotz, J.M. Hamlett, and W.J. Gburek. (2007). Economic and Phosphorus-Related Effects of Precision Feeding and Forage Management at a Farm Scale. J. Dairy Sci. 90:3700–3715. doi:10.3168/jds.2006-836
[231] Rotz, Alan, M. Corson. D. Chianese, F. Montes, S. Hafner, H. Bonifacio, and C. Cioner. (2018) The Integrated Farm System Model Reference Manual Version 4.4
[232] Rotz, C.A. Personal communication. January 26, 2022.

Rotz, Alan, M. Corson. D. Chianese, F. Montes, S. Hafner, H. Bonifacio, and C. Cioner. (2018) The Integrated Farm System Model Reference Manual Version 4.4

Rotz, C. A., S. Asem-Hiablie, S. Place and G. Thoma. 2019. Environmental footprints of beef cattle production in the United States. Agric. Systems 169:1-13.

Rotz, C.A., R. Stout, A. Leytem, G. Feyereisen, H. Waldrip, G. Thoma, M. Holly, D. Bjorneberg, J. Baker, P. Vadas and P. Kleinman. 2021. Environmental assessment of United States dairy farms. J. Cleaner Prod. (2021), doi: https://doi.org/10.1016/j.jclepro.2021.128153.

Veltman, K., C. A. Rotz, L. Chase, J. Cooper, P. Ingraham, R. C. Izaurralde, C. D. Jones, R. Gaillard, R. A. Larsson, M. Ruark, W. Salas, G. Thoma, and O. Jolliet. 2018. A quantitative assessment of beneficial management practices to reduce carbon and reactive nitrogen footprints and phosphorus losses of dairy farms in the Great Lakes region of the United States. Agric. Systems 166:10-25.

APPENDIX 6: DNDC (DeNitrification-DeComposition)[233]

Summary

The DNDC process-based model simulates carbon and nitrogen biogeochemistry in agro-ecosystems on a daily time-step.[234] In addition to inventorying emissions from N_2O, nitric oxide, dinitrogen, ammonia, CH_4 and CO_2, DNDC can be used for predicting crop growth, soil temperature and moisture, carbon dynamics, and nitrogen leaching.[235] DNDC can be used for IPCC Tier 3 methodology since it simulates interactions between soil-plant-atmospheric processes.[236]

The model has two components: the first consists of "the soil climate, crop growth and decomposition sub-models, [to predict] soil temperature, moisture, pH, redox potential (Eh) and substrate concentration profiles driven by ecological drivers (e.g., climate, soil, vegetation and anthropogenic activity)," while the second consists "of the nitrification, denitrification, and fermentation sub-models" to predict emissions from plant-soil systems.[237] The model includes land-use type options for "upland crop field, rice paddy field, moist grassland/pasture, dry grassland/Pasture, wetland, and tree plantation."[238] There are also separate Forest-DNDC and Wetland DNDC models that simulates biogeochemistry in forests and wetlands, as well as a Manure-DNDC model that expands on DNDC's calculations for manure additions to soils to include simulated emissions estimates for different manure management scenarios.[239]

Accurately running a simulation with the tool requires three groups of data: "soil characteristics, daily climate, and crop profile and management. The soil characteristics cover a long set of soil properties such as clay content, organic carbon concentration, initial nitrate and ammonium concentrations, field capacity, wilting point, bulk density, porosity and etc."[240]

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[233] Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, "The DNDC Model," (n.d.) https://www.dndc.sr.unh.edu/. [*hereinafter* UNH].
[234] IPBES, "Policy Support Tool: DNDC DeNitrification-DeComposition," (n.d.), https://ipbes.net/policy-support/tools-instruments/dndc-denitrification-decomposition.
[235] Conservation Technology Information Center, "The Denitrification-Decomposition (DNDC) Model," (2022), https://www.ctic.org/DNDC_Information. [*hereinafter* CITC].
[236] Ward Smith, Personal Interview, February 22, 2022. [*hereinafter* Smith Interview].
[237] *See* CITC.; *also see* Sarah L. Gilhespie et al., "First 20 years of DNDC (DeNitrification DeComposition): Model evolution," *Ecological Modelling* (2014), https://www.sciencedirect.com/science/article/pii/S0304380014004190# . [*hereinafter* Gillespie et al.]: "*Component 1 linked ecological drivers to soil environmental variables and consisted of the soil climate, crop growth and decomposition sub-models. Component 2 linked soil environmental factors to trace gases and consisted of the already known denitrification sub-model and furthermore, the two new sub-models for nitrification and fermentation.*"
[238] Institute for the Study of Earth, Oceans and Space University of New Hampshire, "User's Guide for the DNDC Model," 18 (2012), https://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf.
[239] *See* UNH.; *also see* Chengsheng Li et al., "Manure-DNDC: A biogeochemical process model for quantifying greenhouse gas and ammonia emissions from livestock manure systems," *Nutrient Cycling in Agroecosytems*, (2012), https://link.springer.com/article/10.1007/s10705-012-9507-z. [*hereinafter* Manure DNDC].
[240] Yelin Deng et al., "Incorporating dentrification-decomposition method to estimate field emissions for Life Cycle Assessment," (2017). [*hereinafter* Yelin Deng et al.]

Strengths

Some users of the tool report that it has an attractive interface, and that the tool's outputs are similarly accessible to a wide range of users.[241] DNDC can simulate processes for a range of land uses across varying "climatic zones, soil types, and management regimes."[242] Numerous studies have verified DNDC's accuracy in comparison to observations, including several global studies where it performed well in multi-model comparisons.[243] DNDC's daily time-step modelling makes it more accurate than other tools like CENTURY with a monthly time-step.[244]

DNDC has been found to be more accurate than IPCC methods, which are intended for a much wider scale, and is considered to be "more site specific as it is built according to complex models of soil science."[245] In at least one study DNDC was found to be more accurate than DAYCENT for measuring soil organic carbon,[246] but the models are generally comparable in performance.[247]

Though DNDC is more technically demanding than tools like Holos, DNDC can generate more outputs and can accommodate a much wider range of management practices including 4R (*for definition, see footnote*[248]) and conservation practices.[249] A recently revised version of DNDC simulates carbon change over 2m soil profile depth and vertically stratifies this change in 1 cm increments.[250]

Weaknesses

The primary DNDC model does not include parameterization for field trees, hedges, agroforestry, forestland, wetlands, settlements, or other non-cultivated lands.[251] Furthermore, the DNDC's predictions for N2O emissions from organic manures, and in the absence of additional nitrogen fertilisation, are sometimes reported to be too low.[252]

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241 *See* Gillespie et al.
242 *Id.*, at 8.
243 Changsheng Li, "Calibrating, Validating, and Implementing Process Models for California Agriculture Greenhouse Gas Emissions," 7, (2014), https://ww2.arb.ca.gov/sites/default/files/2020-05/1dndcproposal.pdf.
244 *See* Smith Interview.
245 *See* Yelin Deng et al.
246 Wentian He et al., "Measuring and modeling soil carbon sequestration under diverse cropping systems in the semiarid prairies of western Canada," *Journal of Cleaner Production*, (2021), https://www.sciencedirect.com/science/article/pii/S0959652621037926.
247 *See* Smith Interview.
248 "4R Nutrient Stewardship provides a framework to achieve cropping system goals…the 4R concept incorporates the: **R**ight fertilizer source at the **R**ight rate, at the **R**ight time and in the **R**ight place."; Nutrient Stewardship, "What are the 4Rs," (2017), https://nutrientstewardship.org/4rs/.
249 *Id.*
250 *Id.*
251 *Id.* At 14.
252 *See* Gillespie et al.; However, this is not always the case, *see* Wentian He et al., "Assessing the effects of manure application rate and timing on nitrous oxide emissions from managed grasslands under contrasting climate in Canada," *Science of the Total Environment*, (2020), https://www.sciencedirect.com/science/article/pii/S0048969719353665.

Users have noted difficulty understanding the user manual and stated that restricted access for the DNDC source code makes it difficult to understand the reasoning for changes and code modifications and their impact.[253] "There are also issues with availability of input parameters for specific situations."[254] DNDC has also been identified by some users (but not all, *see footnote*[255]) as "notably extreme in [it's] very high data requirements" and the time required for analysis is "very long."[256] As a result, the skill level necessary to use DNDC effectively is very high.[257]

<u>Opportunities</u>

The Canadian DNDC model is available for free through GitHub, though the US model developed by the University of New Hampshire is accessible through Dr. William Salas (cost unknown).[258]

Separate Forest and Wetland DNDC models have been developed that can be used to provide calculations to supplement whole-farm accounting.[259] Similarly, a Manure-DNDC model can simulate emissions from different manure management systems of storage, application, and biodigestion.[260] The different land use models have not yet been used together to design a single, comprehensive whole-farm assessment, but they could be.[261]

Though DNDC was initially designed to estimate emissions on individual farms, researchers in California were able to reliably simulate regional emissions by linking DNDC to a GIS database.[262] The tool's library of default settings can accommodate 62 crops and 12 soil types, enabling users to "model a wide range of sites and situations without the need for considerable amounts of rarely measured input data.[263] Furthermore, many of these inputs can also be user-defined to accommodate a greater range of possibilities."[264]

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[253] *Id.*; The user can sign and agreement that the model is being used for research purposes, *see* Ward Smith, Personal Interview, February 22, 2022.
[254] *Id.*
[255] "DNDC has moderate inputs requirements. It uses a cascade water flow approach such that we don't need detailed hydraulic parameters and the crop inputs are simple compared to most crops models (DSSAT, APSIM, STICS, etc). I would certainly say the input requires are no more than moderate," and "The base US model takes at most 0.5 seconds per year or 5 seconds for 10 years on a home laptop. I don't think this is "very long" so I again disagree. Computational power is not a major limitation since large projects should have hardware available." *See* Ward Smith, Personal Interview, February 22, 2022.
[256] Anass Toudert et al., "Carbon Accounting Tools for Sustainable Land Management," World Bank Group, 15 (2018), https://openknowledge.worldbank.org/handle/10986/31062.
[257] *Id.*
[258] *See* Smith Interview.
[259] *Id.*
[260] *See* Manure DNDC.
[261] *See* Smith Interview.
[262] *Id.*, at 13.
[263] *See* Gilhespie et al.
[264] *Id.*

In Canada, a DNDC-Management Factor Tool (DNDC-MFT) was developed which links soil, climate, and agricultural activity data to estimate the impacts of changes in agriculture management on N2O emissions and soil organic carbon change.[265]

Threats

As with other tools, DNDC's accuracy comes at the expense of complexity and it is necessary to employ experienced users with a sophisticated understanding of the tool, as well as a strong understanding of agronomy and soil science, to use it effectively.[266] It may therefore be difficult to train enough technicians to deploy the model across the state of Vermont.[267] (for an estimate on training demand for technicians, *see footnote.*[268])

Furthermore, the accuracy of DNDC models relies on the accuracy of the data used and Vermont may need to undertake a large research effort to compile sufficient and accurate information.

[265] Smith, W.N., Grant, B.B., Desjardins, R.L., Worth, D., Li, C., Boles, S.H., Huffman, E.C. (2010). A tool to link agricultural activity data with the DNDC model to estimate GHG emission factors in Canada, 136(3-4), 301-309, https://profils-profiles.science.gc.ca/en/publication/tool-link-agricultural-activity-data-dndc-model-estimate-ghg-emission-factors-canada-0.

[266] *See* Smith Interview.

[267] *Id.*

[268] *Id.* "It could only take one or two skilled people to implement the model, but they would require training, less training if they have already used other process-based models. I think it's important for any modeler, even if they use a simple empirical model, to still have good background/knowledge of agronomy and soil processes, such that they can determine if the results across contrasting soils, climate and management are reasonable."

APPENDIX 7: EPIC (Environmental Policy Integrated Climate) & (APEX) Agricultural Policy Environmental eXtender

Summary

The Environmental Policy Integrated Climate (EPIC) and Agricultural Policy Environmental eXtender (APEX) tools are two variations of a model developed by the Blacklands Research and Extension Center in Temple at Texas A&M University.[269] Both are process-based biogeochemical models that function on a daily time-step and perform IPCC tier 3 simulations.[270]

EPIC was initially developed to assess the impacts of erosion on farm productivity, but was later expanded to assess other processes related to agricultural management[271] and can now also simulate water quality, nitrogen cycling, carbon cycling (based on the CENTURY model), climate change, and the effects of CO_2.[272] Weather information for EPIC/APEX modelling uses WXGN Software that "uses standard deviation instead of skew coefficient for temperature generation; this eliminates erroneous values generated in areas where the mean monthly temperature is at or near zero."[273]

In comparison, APEX builds on EPIC by linking hydrological modeling and has components for routing water, sediment, nutrients, and pesticides across complex landscapes and channel systems to the watershed outlet as well as groundwater and reservoir components.[274] Whereas EPIC has no spatial dimension, "APEX places EPIC into a spatial context, where it can model hydrological flows using algorithms similar to those used in the SWAT model and thus estimate runoff as well as transport and deposition of soil sediment, nutrients, and pesticides."[275] APEX was developed to facilitate multiple subarea scenarios and/or management strategies, which cannot be simulated in EPIC[276] and is the base tool for the Farm-PREP model–developed by

[269] Phillip W. Gassman et al., "The Agricultural Policy Environmental Extender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses," *Iowa State University: Center for Agricultural and Rural Development*, (2009), https://www.card.iastate.edu/products/publications/pdf/09tr49.pdf.
[270] Xiuying (Susan) Wang et al., "APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling," *USDA/NRCS*, 3 (2011), https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012924.pdf. [*hereinafter* Wang].
[271] *See* Wang at 3.
[272] Texan A&M AgriLife, "EPIC & APEX Models," *Blackland Research & Extension Center*, (n.d.), https://epicapex.tamu.edu/about/epic/. [*hereinafter* EPIC & APEX].
[273] Texan A&M AgriLife, "Software|WXGN," *Blackland Research & Extension Center*, (n.d.), https://epicapex.tamu.edu/software/wxgn/ . "*The release of WXGN is restricted to those researchers and individuals working with the modeling team to enhance scientific understanding or application of the model. We encourage those with interest or modification of the model to contact us epicapex@brc.tamus.edu.*"
[274] *See* EPIC & APEX.
[275] Lydia P. Olander & Karen Haugen-Kozyra, "Using Biogeochemical Process Models to Quantify Greenhouse Gas Mitigation from Agricultural Management Projects," *Duke University: Nicholas Institute*, 12-15 (2011), https://nicholasinstitute.duke.edu/sites/default/files/publications/using-biogeochemical-process-paper.pdf. [*Hereinafter* Olander & Haugen-Kozyra].
[276] *See* Wang at 6.

Stone Environmental–that the Vermont Agency of Agriculture Food and Markets (VAAFM) uses to measure phosphorus reductions.[277]

APEX was also selected to estimate the edge of field benefits for the USDA Conservation Effects Assessment Project (CEAP), and APEX's cropland results were also aggregated in the Soil and Water Assessment Tool (SWAT).[278]

The most recent versions of the tools are EPIC v.1102 and APEX v.1501.[279] Updates occur over the course of several years, but APEX is more frequently updated than EPIC because the developers receive greater outside support for APEX.[280]

This summary will include information about both EPIC and APEX because the two tools are closely related and either can have their separate advantages for modelling Vermont agriculture emissions at the whole-farm level[281]—while EPIC could provide more convenient functionality, APEX could be better suited for modelling when measuring edge of field target variables.[282] Additionally, APEX is already employed by the USDA for CEAP and SWAT, and APEX is also already used by VAAFM and can have important applications for Vermont agri-environmental policy like Payment for Ecosystem Services programs.

Strengths

EPIC and APEX include measurements for 150 different crops—including an extensive list of vegetable crops[283]—and forested areas, as well as a tracking mechanism for production costs and crop income for simulating economic outcomes.[284] The tools have been tested and validated by the developers across the US[285] and have the capacity to perform simulations for hundreds or thousands of years.[286] The models' original development for evaluating management practices also gives them a strong foundation in measuring soil productivity and quality.[287]

Furthermore, both models receive robust backing from federal agencies for financial and policy support, as well as from technical staff and Texas A&M University for helping users

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[277] Stone Environmental, "The Farm-P Reduction Planner (Farm-PREP): An Integrated Tool for Optimizing Field Practices to Achieve Farm-Scale Nutrient Reductions," (n.d.), https://www.stone-env.com/assets/resources/6d35ca97df/E_17054-FarmPREP.pdf.
[278] See Wang at 6.
[279] Texan A&M AgriLife, "Manuals and Publications," *Blackland Research & Extension Center,* (n.d.), https://epicapex.tamu.edu/manuals-and-publications/.
[280] Jaehak Jeong & Phillip Gassman personal interview, March 8, 2022. [*hereinafter* Jeong & Gassman interview].
[281] *Id.*
[282] *Id.*
[283] *See* Olander & Haugen-Kozyra at 12-15.
[284] EPIC Development Team, "Environmental Policy Integrated Climate Model: User's Manual Version 0810," *Blackland Research & Extension Center*, 5 (2015), https://epicapex.tamu.edu/media/vw3pbx0b/epic0810-user-manual-sept-15.pdf. "*The FLIPSIM whole farm economic model has been coupled with EPIC to perform economic analyses of irrigated agriculture in Texas.*"
[285] *See* Jeong & Gassman interview.
[286] *Id.*
[287] *Id.*

resolve technical challenges, including through an online EPIC/APEX modelling forum on Google Groups.[288]

EPIC can perform simulations for stored carbon and nitrogen based on the CENTURY model.[289] In a study comparing EPIC to other tools—including DNDC and Daycent—EPIC stood out for being the only tool in the study that accounted for GHGs from upstream fertilizer and pesticide production.[290]

APEX includes a model for extensive grazing and confined area feeding, though the simulation can only accommodate one herd in a subarea at any given time.[291]

Weaknesses

EPIC is designed to simulate fields, farms, or small watersheds that are homogenous across factors for climate, soil, land use, and can simulate "an extensive array of tillage systems and other management practices," so conducting a whole-farm measurement requires individual simulation of multiple fields rather than a single measurement comprised of multiple fields.[292] The tools also do not currently model for enteric emissions, though seed grazing land source code is being integrated into the not-yet-available APEX v.1905 model.[293]

Users of APEX indicate that it can be technically tedious since potentially a large number of corresponding model parameters may need to be predefined or calibrated to properly represent the area of interest. [294] Additionally, the source code is poorly documented and is very difficult to access.[295]

In one assessment that compared models that were developed to specifically focus on carbon and nitrogen dynamics, APEX and EPIC were found to have lower resolution in the ecology of different cropping systems.[296]

Opportunities

Both models are already used by federal and state agricultural programs, making any outcomes from modelling Vermont emissions compatible with those pre-existing programs. Specifically considering APEX, the high expertise-level required to effectively use the tools

[288] *Id.*; *See* Google Groups, "EPIC/APEC Modeling Forum," https://groups.google.com/g/agriliferesearchmodeling.
[289] *Id.*
[290] *See* Olander & Haugen-Kozyra at 12-15.
[291] *Id.*
[292] *Id.* at ii.
[293] *See* Jeong & Gassman interview.
[294] Kiuyang Want & Jaehak Jeong, "APEX-CUTE 4 User Manual," *Texas A&M AgrifLife Research*, (2016), https://temp-web1.brc.tamus.edu/media/gtnivg5p/apexcute-user-manual_v46.pdf.
[295] *See* Jeong & Gassman interview.
[296] Christina Tontito et al., "Quantifying Greenhouse Gas Emissions from Agricultural and Forest Landscapes for Policy Development and Verification," *Advances in Agricultural Systems Modeling, Volume 6*, (2016), https://repository.si.edu/bitstream/handle/10088/32927/Tonitto-etal-GHGmodelReview16.pdf?sequence=1&isAllowed=y.

could be mitigated because of Vermont Technical Assistance Providers' familiarity with Farm-PREP and VAAFM's established relationship with Stone Environmental.

Also, regarding the tools' required technical sophistication, developing a more user-friendly interface—similar to the work already done on Farm-PREP—could make them more broadly deployable for Vermont agriculture initiatives, both for measuring emissions and for a potential PES program.[297]

Other opportunities include ongoing developments of the tools—in addition to the forthcoming integration of grazing land source code to simulate enteric emissions in APEX v.1905, developers are also working to give bigger scale perspectives for agricultural impacts to air and groundwater quality.[298]

Threats

As discussed, the tools' sophistication could make it difficult to train enough staff to use this tool across Vermont. Also, like other models, the quality of outputs depends on the quality of inputs and routinely updating to reflect changes in management technologies, cropping systems, and climate and calibrated as new data becomes available.

[297] *See* Jeong & Gassman interview.
[298] *Id.*

APPENDIX 8: COOL-Farm

Summary

The Cool Farm Tool (CFT) is owned and managed by the Cool Farm Alliance, an international organization of consumer goods producers, retailers, non-governmental organizations, fertilizer producers, and small and medium-sized enterprises.[299] CFT was developed in 2008[300] and put online in 2013[301] as open-source software.[302] CFT is a decision support tool that models estimates of greenhouse gases (GHGs), biodiversity, and water footprint. [303] GHG reduction and carbon sequestration are calculated on a per field basis with calculations from over 100 global data sets, peer reviewed studies, and IPCC methods,[304] derived mostly from IPCC Tier 1 and Tier 2.[305] Biodiversity calculations capture the ability of the farm to support biodiversity through four dimensions and 11 species groups.[306] CFT Water metrics measures irrigation use and optimization for crop yield and freshwater conservation.[307]

Strengths

A unique strength of this tool is its international reach which provides a standard tool and results for easy comparison.[308] CFT has many corporate stakeholder members which increases the likelihood of its use and development. It was designed to have a high degree of applicability to what occurs on farms and be user-friendly for farmers. To calculate product carbon footprint, it accounts for carbon sequestration[309] (above and below ground)[310], nitrogen inhibitors,[311] wastewater from processing[312], etc. CFT accounts for GHG emissions from a wide variety of

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[299] Kayatz, Benjamin, G. Baroni, J. Hillier, S. Lüdtke, R. Heathcote, D. Malin, C. van Tonder, B. Kuster, D. Freese, R. Hüttl, M. Wattenbach. (2019). Cool Farm Tool Water: A global on-line tool to assess water use in crop production. Journal of Cleaner Production. Vol 207. 1163-1179. doi.org/10.1016/j.jclepro.2018.09.160.
[300] *Id.*
[301] CFT. 2019. "Methods Papers." Greenhouse Gases. https://coolfarmtool.org/coolfarmtool/greenhouse-gases/
[302] Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.
[303] CFT. 2019. Dashboard. https://coolfarmtool.org/coolfarmtool/
[304] CFT. 2019. "Methods Papers." Greenhouse Gases. https://coolfarmtool.org/coolfarmtool/greenhouse-gases/
[305] Vetter, Sylvia, D. Malin, P. Smith, J. Hillier. (2018). The potential to reduce GHG emissions in egg production using a GHG calculator – A Cool Farm Tool case study. Journal of Cleaner Production. Vol. 202. 1068-1076. doi.org/10.1016/j.jclepro.2018.08.199.
[306] CFT. 2019. Biodiversity. https://coolfarmtool.org/coolfarmtool/biodiversity/
[307] CFT. 2019. Water. https://coolfarmtool.org/coolfarmtool/water/
[308] Aschbacher, Michaela. Personal communication. February 16, 2022.
[309] CFT. 2019. "Methods Papers." Greenhouse Gases. https://coolfarmtool.org/coolfarmtool/greenhouse-gases/
[310] Aschbacher, M. Personal communication (March 23, 2022).
[311] Cool Farm Alliance. 2016. "The Cool Farm Tool Data Input Guide -- Crops." http://coolfarmtool.wpengine.com/wp-content/uploads/2016/09/Data-Input-Guide.pdf
[312] Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.

livestock sources and manure storage methods, including grazing[313] and can be applicable to diversified farms.[314] Biodiversity scores are based on expert opinion and additional points are awarded when scientific documentation supports it.[315] To calculate blue and green water footprints, CFT Water utilizes local climate data[316] and the FAO56 standard to simulate soil water dynamics (e.g., runoff, interception, the effect of organic matter)[317]. CFT aims to keep current with changes made to IPCC guidelines[318] and is transparent about changes with well-documented, publicly accessible updates document.[319]

CFT is currently being used and co-developed by the 131[320] members of the Cool Farm Alliance and is a well-documented tool with over 30 scientific publications published.[321] The CFT corroborates other research,[322] such as that conducted by Lal published in 2004[323] and Ledo.[324] Cool Farm Alliance created an Innovation Hub to increase the scientific rigor of CFT by engaging in research partnerships.[325] Current research partners include University of Aberdeen, University of Oxford, University of Cambridge, GFZ German Research Centre for Geosciences, and Wageningen University and Research.[326] Cool Farm Alliance offers a free E-Learning course on CFT.[327]

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313 Vetter, Sylvia, D. Malin, P. Smith, J. Hillier. (2018). The potential to reduce GHG emissions in egg production using a GHG calculator – A Cool Farm Tool case study. Journal of Cleaner Production. Vol. 202. 1068-1076. doi.org/10.1016/j.jclepro.2018.08.199.

314 Aschbacher, Michaela. Personal communication. February 16, 2022.

315 CFT. 2019. Biodiversity. https://coolfarmtool.org/coolfarmtool/biodiversity/

316 Cool Farm Alliance. 2017. "CFT Water Assessment Description." http://coolfarmtool.wpengine.com/wp-content/uploads/2017/07/CFA-Water-Description.pdf

317 CFT. 2019. "Methods Papers." Water. https://coolfarmtool.org/coolfarmtool/water/

318 Cool Farm Alliance. 2019. "Cool Farm Tool: Updates to the 2019 IPCC Guidelines for Greenhouse Gas Inventories." News & Resources. https://coolfarmtool.org/2022/01/cool-farm-tool-updates-to-the-2019-ipcc-guidelines-for-greenhouse-gas-inventories/

319 Cool Farm Alliance. 2019. "Updating the Cool Farm Tool Calculation – CFT Version 1.0 Release Plan." News & Resources. https://coolfarmtool.org/2021/07/updating-the-cool-farm-tool-calculation-cft-version-1-1-release-plan/

320 Aschbacher, M. Personal communication (March 23, 2022).

321 Kayatz, Benjamin, G. Baroni, J. Hillier, S. Lüdtke, R. Heathcote, D. Malin, C. van Tonder, B. Kuster, D. Freese, R. Hüttl, M. Wattenbach. (2019). Cool Farm Tool Water: A global on-line tool to assess water use in crop production. Journal of Cleaner Production. Vol 207. 1163-1179. doi.org/10.1016/j.jclepro.2018.09.160.

322 Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.

323 Lal, R. (2004). Carbon emissions from farm operations. Environ. Int. 30 981-990. doi.org/10.1016/j.envint.2004.03.005

324 Ledo, Alicia, R.Heathcote, A.Hastings, P.Smith, J.Hillier. (2018) Perennial-GHG: A new generic allometric model to estimate biomass accumulation and greenhouse gas emissions in perennial food and bioenergy crops. Environmental Modelling & Software. 102 292-305. doi.org/10.1016/j.envsoft.2017.12.005

325 Cool Farm Alliance. 2019. "Overview." Research Partnerships. https://coolfarmtool.org/research/research-partnerships/

326 Cool Farm Alliance. 2019. "Overview." Innovation Hub. https://coolfarmtool.org/research/innovation-hub/

327 Cool Farm Alliance. 2019. "Free E-Learning Course on the Cool Farm Tool." News & Resources. https://coolfarmtool.org/2021/06/free-e-learning-course-on-the-cool-farm-tool/

Weaknesses

CFT only calculates the impact of pesticides on radiative forcing (GHG) and not its other impacts on air, water, or soil,[328] and also does not account for social impacts. However, a cost balance for income and expenses can be made on an individual assessment level. Other aspects such as biochar, feed additives, closed environments (e.g., greenhouses and soilless growing operations) are not yet available but are currently in development.[329] Although CFT accounts for conversion into and out of forest, it does not account for working woodlot forest management.[330] Not all data requirements or management options are posted online. Although CFT can calculate GHGs for many crops, it is not a streamlined process yet as a whole-farm assessment.

The biodiversity tool is currently only for the temperate forest and Mediterranean and semi-arid biome, while tropical forests still need to be finalized. This might not cover every, but most of the production regions worldwide.[331] The maximum biodiversity score is only attainable if the farm implements all recommended practices and has all habitat types i.e. is a mixed farm.[332] Biodiversity thresholds have not yet been established.[333] CFT Water requires assessments of all fields for whole farm or basin assessment, uses well water grass crop as reference point (uses single crop coefficient curve to adjust for other crops), and does not calculate a grey water footprint.[334]

Future iterations of CFT Water are expected to provide additional GHG assessments (including fertigation options), expand crop type selection, estimate potential catchment water scarcity, increase soil water balance parameters details, and aggregate information at the whole farm level.[335] CFT estimates GHGS based on annual averages and is not able to calculate GHGs on a daily basis.

CFT is not a lifecycle assessment (LCA) tool but can be used as a tool for LCA analysis.[336] Although CFT is robust in its analysis of Tier 1 and Tier 2, it uses a simplified version of Tier 3 (multi-factorial empirical model) which quantifies the impact of nitrogen

[328] Cool Farm Alliance. 2016. "The Cool Farm Tool Data Input Guide -- Crops." http://coolfarmtool.wpengine.com/wp-content/uploads/2016/09/Data-Input-Guide.pdf
[329] Aschbacher, Michaela. Personal communication. February 16, 2022.
[330] Cool Farm Alliance. 2016. "The Cool Farm Tool Data Input Guide -- Crops." http://coolfarmtool.wpengine.com/wp-content/uploads/2016/09/Data-Input-Guide.pdf
[331] Aschbacher, M. Personal communication (March 23, 2022).
[332] Cool Farm Alliance. 2016. "CFT Biodiversity Metric Description." http://coolfarmtool.wpengine.com/wp-content/uploads/2016/10/CFT-Biodiversity-Method-Description.pdf
[333] CFT. 2019. Biodiversity. https://coolfarmtool.org/coolfarmtool/biodiversity/
[334] Cool Farm Alliance. 2017. "CFT Water Assessment Description." http://coolfarmtool.wpengine.com/wp-content/uploads/2017/07/CFA-Water-Description.pdf
[335] *Id.*
[336] Cool Farm Alliance. 2019. "Is the Cool Farm Tool compliant with standards such as the WRI GHG Protocol ISO, PAS2050, Carbon Trust, Life Cycle Analysis, the International Dairy Federation etc?" News & Resources. https://coolfarmtool.org/faqs/is-the-cool-farm-tool-compliant-with-standards-such-as-the-wri-ghg-protocol-iso-pas2050-carbon-trust-life-cycle-analysis-the-international-dairy-federation-etc/

application, soil carbon sequestration, emissions from residue management, energy, and other sources. [337, 338] As with all models, there are degrees of uncertainty in output related to calculations and algorithms. CFT is working toward reducing uncertainties and documenting them for user reference. The CFT does not account for soil C stock changes as a result of plant biomass changes i.e. under perennial forage.[339] However, it does account for soil C stock changes from switching land use from arable to grassland.[340] Due to N_2O release variability from fertilizer on poorly drained soils under different tillage managements (no-till vs till), the CFT is not able to model this scenario.[341] Like other agricultural GHG models, CFT exhibits "substantial uncertainties for studies which display large soil CO_2 emissions/sequestration or direct N_2O emissions."[342] Therefore, the best application of CFT may be for an initial assessment to identify best mitigation practice options. In some cases, the tools may be too general to capture nuances in management i.e. does not accommodate 'it depends' scenarios. CFT cannot meet every goal of every organization.

Opportunities

It is free for farmers[343] and is non-prescriptive as it shows impact of changes and identifies fields where the biggest impact can be made. There is opportunity to use the CFT GHG tool to model GHG reductions and carbon sequestration. The biodiversity tool metrics are applicable in Vermont.[344] However, CFT does not provide a price associated with management changes that impact GHG, biodiversity, or water quality. CFT can be a tool for organizations, like Mars and PepsiCo who want to broaden their focus from practices to outcomes.[345] As with one of northern Europe's leading meat companies, Atrias' 32 pig farms, The Cool Farm Tool can be used on food product packaging to inform consumers of carbon footprint associated with primary production and other factors in association with production of the product.[346] Other

[337] Hillier, Jon. (2013). The Cool Farm Tool. Powerpoint presentation. https://www.fao.org/fileadmin/user_upload/epic/docs/workshops/Technical_consultation/Presentations/CFT_intro.pdf
[338] Aschbacher, M. Personal communication (March 23, 2022).
[339] Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.
[340] Aschbacher, M. Personal communication (March 23, 2022).
[341] Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.
[342] *Id.*
[343] CFT. 2019. Dashboard. https://coolfarmtool.org/coolfarmtool/
[344] Cool Farm Alliance. 2016. "CFT Biodiversity Metric Description." http://coolfarmtool.wpengine.com/wp-content/uploads/2016/10/CFT-Biodiversity-Method-Description.pdf
[345] Cool Farm Alliance. 2019. "Leverage points to scale regenerative agriculture and GHG emission reductions." News & Resources. https://coolfarmtool.org/2021/06/leverage-points-to-scale-regenerative-agriculture-and-ghg-emission-reductions/
[346] Cool Farm Alliance. 2019. "Finish Brand First to Communicate Pork Carbon Footprint On-Pack." News & Resources. https://coolfarmtool.org/2021/12/finish-brand-first-to-communicate-pork-carbon-footprint-on-pack/

businesses like Stonyfield and Ben & Jerry's (Unilever) are using CFT with farmers in a pilot program to reduce GHG emissions and encourage regenerative agriculture.[347] The results of CFT indicate areas of improvement, but do not make recommendations. Future improvements could include a list of practices that would help minimize GHG footprints and improve biodiversity. Furthermore, as is occurring in Australia in response to new European and Asian export requirements, businesses are partnering with each other and farmers to mitigate GHG emissions and using the CFT to document changes.[348] The CFT offers an opportunity for shared learning as it creates a robust database and this can help inform cost-effective approaches.[349]

To meet the goals of organizations that use CFT, other models or additional questions can be utilized. For example, CFT can be used with EX-ACT to model crop productivity, farm economics, and optimization of decreasing GHG emissions.[350] Because of its wide-use and easy integration with other models, CFT can be used to inform policy decision or in PES programs. Currently, Agreena and Soil Capital are using CFT to inform monetization of carbon and sustainability.[351, 352]

Threats

As with any modeling system, the model needs to be maintained, calibrated with new data, and expanded to support new management techniques, technology, or cropping systems. Currently, maintenance of CFT is supported to respond to changes in standardized methods or farmer operational changes. Rigorous scientific review of model outputs may delay implementation until verification is complete. CFT seems to be most widely utilized in scenarios where there are research, business, or compliance incentives to do so. A unique threat to CFT is that its development priorities may be influenced by its members as many of its members are primary funders so its development may be influenced by market forces as agricultural and policy actions can sometimes be dependent on commercial interests.[353] Thus, if stakeholders

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[347] Cool Farm Alliance. 2019. "Farmer Interviews: The Cool Farm Tool as an Enabler of Regenerative Agriculture." News & Resources. https://coolfarmtool.org/2021/12/farmer-interviews-the-cool-farm-tool-as-an-enabler-of-regenerative-agriculture/

[348] Cool Farm Alliance. 2019. "Learnings from the COOL SOIL INITIATIVE: Using the Cool Farm Tool to Drive Transformation at Scale in Soil Health and Farmer Resilience." News & Resources. https://coolfarmtool.org/2021/10/learnings-from-the-cool-soil-initiative-using-the-cool-farm-tool-to-drive-transformation-at-scale-in-soil-health-and-farmer-resilience/

[349] Cool Farm Alliance. 2019. "Leverage points to scale regenerative agriculture and GHG emission reductions." News & Resources. https://coolfarmtool.org/2021/06/leverage-points-to-scale-regenerative-agriculture-and-ghg-emission-reductions/

[350] Hillier, Jonathan, C. Walter, D. Malin, T. Garcia-Suarez, L. Mila-i-Canals, P. Smith. (2011). A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software. Vol 26 (9) 1070-1078 doi.org/10.1016/j.envsoft.2011.03.014.

[351] Aschbacher, Michaela. Personal communication. February 16, 2022.

[352] Cool Farm Alliance. 2021. "CFA Annual Meeting 2021 – A Day of Solutions in Action." News & Resources. https://coolfarmtool.org/2021/05/cfa-annual-meeting-solutions-in-action/

[353] Aschbacher, Michaela. Personal communication. February 16, 2022.

choose to develop their own tool, funding could drop for CFT and relevancy may decrease if it loses widespread international use.

Additionally, its global reach may limit its adaptability to the needs (practices and terminology) of particular regions. However, an application programming interface (API) provides a method of compatibility with other systems. As is true for many modeling software, it is rare that a farmer would utilize this tool without support, financial incentive, or regulatory requirement. Like any payment for ecosystem programs, programs that support changes on farms with CFT may not be able to offer compensation past a limited time which can impact farm planning, incentive to invest, and program permanence.

Results from management changes can take years to manifest and this may be a source of frustration for farmers, regulators, or purchasers of farm products that want more immediate results. Utilization of the model requires learning how to use the tool or working with dedicated staff that have the training and skills to use it correctly. Cool Farm Alliance has reduced this barrier with a free e-learning course. Likewise, the quality of the model's outputs depends on the availability and quality of data entered into the model which depends on farmer time and records.

For more information on strengths and limitations of the Cool Farm water model:

Kayatz, Benjamin, G. Baroni, J. Hillier, S. Lüdtke, R. Heathcote, D. Malin, C. van Tonder, B. Kuster, D. Freese, R. Hüttl, M. Wattenbach. (2019). Cool Farm Tool Water: A global on-line tool to assess water use in crop production. Journal of Cleaner Production. Vol 207. 1163-1179. doi.org/10.1016/j.jclepro.2018.09.160.

APPENDIX 9: *Table 1*-Model Input Requirements

Program	Scale / Location Designation	Crop history (number of years of rotation, tillage, fertilizer management, etc.)	Manure management (storage types)	Fuel use (none, only on farm or off-farm too)
Holos	Eco-District	1 year farm history	Y	On farm and off-farm
DayCent	Long/latitude (point-based or gridded data)	Crop or pasture yield and field management practices beginning in 2000, earlier information can be entered if available	N	N
Comet-Farm	Select field location	General pre-2000 information, management practices post-2000	Y	On farm only with Comet-Energy
Comet-Planner	County	1 year	N	Y for combustion system improvement, only if practice is selected
Integrated Farm System Model (IFSM)	Select farm location	1 year of crop history (yield, inputs, field management)	Y	On farm and off-farm
DNDC	Long/latitude (point-based or gridded data)	Current field management practices	Y, in Manure-DNDC	N
EPIC/APEX	Long/latitude	Current field management practices	Y (in APEX)	On farm and off-farm
Cool-Farm	Long/latitude. User inputs average yearly temperature	1 year of crop history (yield, inputs, tillage)	Y (but not length of storage)	On farm and off-farm
Ex-Act*	Regional	Current and (speculated) future management	Y	On farm and off-farm
SIT (Ag and LULUCF modules)*	State, sector	Crop production data for each year	Y	No (reflected in other modules)

APPENDIX 10: *Table 2*-Model Inputs

DNDC	IFSM	DayCent	Holos	EPIC	APEX
Site and climate	Crop and soil	Daily max/min air temp/precipitation as input parameter files	Site boundaries	Sites	Sites
Soil	Grazing	Surface soil texture class	Farm management	Subarea	Subarea
Farming management	Machinery	Land cover	Stocking numbers	Soils	Soils
Crop	Tillage and planting	Land use data	Crop management	Field operation schedules	Field operation schedules
Tillage	Crop harvest	Tillage		Weather	Weather
Fertilization	Feed storage	Fertilization		User determines number of projection years	User determines number of projection years a
Manure management	Herd and feeding	Grazing and cutting			
Plastic film use	Manure management	Irrigation			
Flooding	Economic parameters	Harvest type and date			
Irrigation		Organic matter applications			
Grazing and cutting					

APPENDIX 10: *Table 2*-Model Inputs (cont'd)

COMET-Farm	COMET-Planner	COOL-Farm:Crop	COOL-Farm: Livestock
Field Boundary	County	Crop type and planting date	Herd size and composition
Historical data since 2000	NRCS Practice(s) (dropdown)	Crop year	Milk production, fat content, and protein content
Crop Rotations	Acres of practice(s)	Harvest date & yield	Grazing time by cow category
Planting, harvest dates, & yields		Growing area	Feed type and amount
Tillage System		Soil information (texture, SOM, moisture, drainage, pH)	Manure storage type
Rate, timing, type of manure and fertilizer applications		Rate and method type of fertilizer applications (with or without N inhibitor)	On-farm energy use (electricity and fuel)
Irrigation method and rate		Rate, timing, and method type of pesticide applications	Transportation of goods on and off farm
Residue management (burning)		Fertilizer and pesticide production region for upstream GHG region calculations	-
Herd size and composition		Changes in land use (into/out of forest or grassland)	
Manure management system		Irrigation method and rate	
Optional: Fuel & electricity use, through COMET-Energy tool		Tillage practices	
		Cover crop practices	
		Residue management (dropdown options)	
		Fuel and electricity use	
		On-farm energy use (electricity and fuel)	
		Transportation of inputs and harvest (optionally)	
		Wastewater	
		Transportation of inputs and harvest (optionally)	
		Wastewater	

APPENDIX 10: *Table 2*-Model Inputs (cont'd)

EX-Act*	SIT (Ag Module)*	SIT (LULUCF Module)*
Geographic area	Emission factors by animal type	Carbon emitted from or sequestered in aboveground & belowground biomass
Climate & soil characteristics	Animal population numbers	Carbon sequestration factor for urban trees
Duration of project	Typical animal mass	Total urban area
Deforestation	Volatile solids production	Urban area tree cover
Afforestation/reforestation	Maximum potential CH4 emissions	Direct N2O emission factor for managed soils
Non-forest LUC	Kjeldahl nitrogen excreted	Total synthetic fertilizer applied to settlements
Agronomic practices	Crop production	Emission factors for CH4 and N2O emitted from burning forest and savanna
Tillage practices	Fertilizer utilization	Combustion efficiency of different vegetation types
Water & nutrient management	Emission factors for limestone and dolomite	Average biomass density
Manure application	Total limestone and dolomite applied	Area burned
Grassland management practices	Emission factors from urea fertilizer	Grass, leaves, and branches constituting yard trimmings
Feeding practices	Total urea applied to soils	Yard trimmings and foods scraps landfilled, 1960-present
Forest degradation	Residue/crop ratio	Yard trimming management and initial carbon content
Drainage of organic soils	Residue burning management and efficiencies	Carbon emitted from or sequestered in mineral and organic soils on cropland and grassland
Peat extraction		
Fertilizer & agro-chemical use		
Fuel & electricity use		

APPENDIX 11: *Table 3*-Model Parameters

Program	Modeling approach	Scope of analysis	Time-step	Model calibrated
Holos	Bookkeeping (Emissions factors)	Whole Farm	Yearly	Canada Eco-districts
DayCent	Process-based	Crop, fields	Daily	International
Comet-Farm	Process-based & bookkeeping (Emissions factors)	Whole farm, by category (cropland/pasture/range/orchard/vineyard, animal agriculture, agroforestry, and forestry)	Daily	National
Comet-Planner	Bookkeeping (Emissions factors)	By crop (number of acres)	Yearly	National
Integrated Farm System Model	Process-based	Whole Farm	Daily	Primarily northern US and southern Canada, applicable to broader US & Canada
DNDC	Process-based	Field C&N cycling	Daily	International
EPIC/ APEX	Process-based	Whole Farm	Daily	International, but only for select nations
Cool-Farm	Bookkeeping (Empirical and emissions factors)	Whole farm by crop or livestock product; biodiversity at a whole-farm scale	Annual	International
Ex-Act*	Bookkeeping (Emissions factors)	Fields, whole Farm, sector, state	Annual	Regional (sub-continent)
SIT (Ag and LULUCF modules)*	Bookkeeping (Emissions factors)	State, sector	Annual	State

APPENDIX 11: *Table 3*-Model Parameters

Program	Farm type	Climate zones	Soil types	Weather source
Holos	18 types of crops, beef, dairy, swine, poultry, other livestock	Applied by Eco-district	Canadian Soil Information System National Ecological Framework	Canadian Soil Information System National Ecological Framework
DayCent	Major crops and grassland	Site-specific uses weather station, national uses PRISM, for global or others can use any user desired databases	Can be site-specific, SSURGO, user can use any desired database.	Site-specific uses weather station, national uses PRISM, for global or others can use any user desired databases
Comet-Farm	Diverse (crops, livestock, orchards, etc.)	Site-specific	Site-specific, SSURGO	PRISM
Comet-Planner	Cropland, grazing, woody, cropland to herbaceous cover, restoration of disturbed lands	County, Major Land Resource Areas	County, Major Land Resource Areas	PRISM
Integrated Farm System Model	Main crops, dairy, and beef	Site-specific, user can input weather data	User inputs soil texture & can modify soil characteristics	Recorded data or PRISM
DNDC	Crops and livestock	Site-Specific	Site-Specific	User determined
EPIC/ APEX	Extensive Crops	Site-Specific	Site-Specific	WXGN Software
Cool-Farm	Emission footprint can be generated separately by crop (main crops and some speciality (apples, strawberries, etc.)) or livestock, aggregates for whole-farm assessment	User chooses temperate or tropical (used for GHG emissions)	n/a, user inputs texture, SOM, moisture, drainage, and pH	ERA 5, for water module
Ex-Act*	Crops, livestock, aquaculture	Regional	Regional	Harmonized World Soil Database and CGIAR Consortium for Spatial Information
SIT (Ag and LULUCF modules)*	Crops, livestock	State	State	Pre-loaded federal data

APPENDIX 11: *Table 3*-Model Parameters (cont'd)

Program	Weather time (number of years model uses)	Conducts economic analysis (based on default 10 year averages, etc.) (yes/no)	Suitable for diversified farm operations (y/n)	Capacity to include forest
Holos	30	Y	Y	Can extrapolate from lineal tree plantings and riparian zones
DayCent	User determined	N	Y	Y
Comet-Farm	10	N	Y	Y
Comet-Planner	1	N	Y	Y
Integrated Farm System Model	1 to 25	Y, user inputs costs	N	N
DNDC	User defined	N	Y	Separate forest and wetland DNDC-models could be used in conjunction
EPIC/ APEX	n/a	Y, user inputs costs	Y	Y
Cool-Farm	1	N	Y, User can aggregate crop and livestock data for whole-farm assessment	As land use change
Ex-Act*	Unknown	N	Y	Yes
SIT (Ag and LULUCF modules)*	Unknown	N	Y	Y

APPENDIX 12: *Table 4*-Model Output

Program	Scale	GHG emission reduction	Enteric emissions (y/n)	Carbon sequestration (y/n)	Water quality
Holos	IPCC 2 & 3	CO_2, CH_4, N_2O	Y	Y	Forthcoming in next version
DayCent	IPCC 3	CO_2, CH_4, N_2O, NOX, N_2	N	Y	Some NO_3 leaching, but lacks hydrological model
Comet-Farm	IPCC 1, 2, & 3	C, CO_2, CO, N20, CH_4	Y	Y	N
Comet-Planner	IPCC 1, 2, & 3	CO_2, N_2O, CH_4	n/a, no corresponding NRCS standard	Y	N
Integrated Farm System Model	IPCC 3	CO_2, N_2O, CH_4, NH_3, NO_x, N_2	Y	Y	Y, (N leaching and P loss by erosion)
DNDC	IPCC 3	N_2O, NO, N_2, NH_3, CH_4 & CO_2	Y, in Manure-DNDC	Y	Y
EPIC/APEX	IPCC 3	CO_2, NO_2, N_2O, N_2, O_2,	N	Y	Y
Cool-Farm	IPCC 1 & 2	CO_2, N_2O, CH_4	Y	Y	N
Ex-Act*	IPCC 1 & 2	CH_4, N_2O, and selected other CO_2 emissions	Y	Y	N
SIT (Ag and LULUCF modules)*	IPCC 1 & 2	CO_2, N_2O, CH_4	Y	Ag module No; LULUCF module Yes	N

APPENDIX 12: *Table 4*-Model Output (cont'd)

Program	Biodiversity	Compares to alternative cropping scenarios (y/n)	Compares to alternative weather scenarios (y/n)	Water footprint (y/n)	Pesticide impacts (y/n)
Holos	N	N, user can do by running multiple simulations	N, user can do by comparing output by year	Forthcoming in next version	Y, GHG emissions, no toxicological impacts
DayCent	N	Y	Y	N	N
Comet-Farm	N	Y	N	N	N
Comet-Planner	N	Y	N	N	N
Integrated Farm System Model	N	N, user can do by running multiple simulations	N, user can do by comparing output by year or multiple climate simulations	Y	Y, as GHG emission and economic cost
DNDC	N	N, user can do by running multiple simulations	N, user can do by comparing output by year	Y	N
EPIC/APEX	N	N, user can do by running multiple simulations	N, user can do by comparing output by year	Y	Y
Cool-Farm	Y (whole farm)	N, user can do by running multiple simulations	N	Y	Y, GHG emissions, no toxicological impacts
Ex-Act*	N	N	N, user can do by comparing output by year	N	Y, GHG emissions, no toxicological impacts
SIT (Ag and LULUCF modules)*	N	N	N	N	N

APPENDIX 13: *Table 5*-Model Use and Usability

Program	Model support	Level of support	Program available for free (y/n)	Used by other programs
Holos	Agriculture and Agri-Food Canada	Robust	Y	LogiAg
DayCent	Colorado State University	Robust	Y	Is an underlying soil carbon model for COMET
Comet-Farm	Colorado State University, USDA	Robust	Y	Many programs use COMET-Farm methodology
Comet-Planner	Colorado State University, USDA	Robust	Y	Cali. Health Soils Program; American Farmland Trust's CaRPE tool; Climate Smart Commodity grant program
Integrated Farm System Model	ARS USDA	Robust short-term, long-term unknown	Y	Primarily Research, some university courses, UW/ Organic Valley LCA
DNDC	UNH/Geosolutions	Robust	Y	Primarily Research
EPIC/APEX	Blacklands Research and Extension Center	Robust, long-term	Forthcoming in next version	Conservation Effects Assessment Project (CEAP), Soil and Water Assessment Tool (SWAT), VT Pay-for-Phosphorus Program
Cool-Farm	Cool Farm Alliance	No long-term guaranteed funding, but robust industry support and university collaboration	Y for farmers	Atria, geoFootprint, Stoneyfield, and others. For a complete list of members see: https://coolfarmtool.org/cool-farm-alliance/members/
Ex-Act*	FAO	Robust	Y	FAO, VT Carbon Budget
SIT (Ag and LULUCF modules)*	EPA	Robust	Y	EPA, State Inventories

APPENDIX 13: *Table 5*-Model Use and Usability (cont'd)

Program	User-friendly	Application	Data privacy
Holos	High	General estimates	n/a, tool is downloaded, not based in cloud
DayCent	Moderate	Primarily research	n/a, tool is downloaded, not based in cloud
Comet-Farm	Moderate	General estimates	Y, data entered is not used, shared, or viewed by the USDA.
Comet-Planner	High	General estimates	Y, data entered is not used, shared, or viewed by the USDA.
Integrated Farm System Model	Moderate	Primarily research	n/a, tool is downloaded, not based in cloud
DNDC	Low	Primarily research	n/a, tool is downloaded, not based in cloud
EPIC/APEX	Low	Primarily research	n/a, tool is downloaded, not based in cloud
Cool-Farm	High	Corporate tracking and reporting	Y, if shared data anonymized. For privacy policy see: https://app.coolfarmtool.org/privacy/
Ex-Act*	Moderate	General estimates	n/a, tool is downloaded, not based in cloud
SIT (Ag and LULUCF modules)*	High	General estimates	n/a, tool is downloaded, not based in cloud

Appendix S

Creating a Payment for Ecosystem Services (PES) Program Focused on Soil Health in Vermont:

Program Design Issues and Recommendations

Prepared for:

Vermont Payment for Ecosystem Services and Soil Health Working Group

Prepared by:

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In Collaboration with The UVM Technical Team

April 29th, 2022

This report is the primary output from Task 8 of the project titled *Research Technical Services for the Payment for Ecosystem Services and Soil Health Working Group* which is implemented by the Gund Institute at the University of Vermont in collaboration with Conservation Performance LLC. Questions or comments on this report can be directed to Dr. Jon Winsten at Winsten.VT@gmail.com.

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Executive Summary

This report is an assessment of program design issues related to a payment for ecosystem services (PES) program focused on soil health in Vermont. The many decisions needed to create this program are to be made by the Vermont Payment for Ecosystem Services and Soil Health Working Group. As such, this document was designed to provide some context for designing an outcome-based soil health PES program, highlight important program design criteria, and discuss specific program design issues that will need to be addressed by the Working Group.

Payment for ecosystem services programs are a way to reward farmers for taking actions that benefit the environment and society and are an increasingly common alternative to regulations, when appropriate. An outcome-based PES program pays for some type of quantified outcome, as opposed to paying for the implementation of one or more specific practices. The advantages of an outcome-based program include more flexibility for farmers which can lead to innovation and greater cost-effectiveness, as well as a stronger link with the ultimate environmental goals of the program. The primary challenges of an outcome-based program include designing an appropriate quantification and verification system and preventing the program's transaction costs from outweighing its benefits.

Focusing the PES program on soil health is a unique and potentially valuable approach. Soil health is not an ecosystem service but is a necessary condition (and therefore a proxy) for several ecosystem services. There are at least two important advantages of focusing on soil health. First and foremost, improvements in soil health can increase soil productivity and farm profitability. As such, the field management changes motivated by the PES program are much more likely to be maintained even if the program ceases to exist in the future. Second, soil health is a function of variables that can be measured relatively easily and, as such, does not depend on computer simulation modeling, as does nutrient loss or greenhouse gas (GHG) emissions. On the other hand, soil health is not a direct and certain measure of the ecosystem services that we hope will result from it, such as carbon storage, water retention, flood resilience, etc. In the absence of sufficient science, we are forced to assume that these ecosystem services, the public goods the program is primarily investing in, will result from improvements in soil health.

This report makes the case that clear and explicit program goals and objectives are essential and will greatly facilitate decision-making for the plethora of issues that the Working Group will have to address. The criteria for designing a successful PES program include cost-effectiveness, financial feasibility, practicality of implementation, program compatibility, and transparency. Each of these are discussed in the report and it will be up to the Working Group to prioritize their criteria.

In this report numerous specific program design issues are assessed. For each issue, the report provides background and context, input from the Working Group, including survey results, and, where appropriate, some recommendations. A summary of the conclusions and recommendations is shown below.

Participant eligibility

- Eligibility should be open to all Vermont farms as defined in Section 3.1 of the Required Agricultural Practices Rule. However, the Working Group will need to decide:
    - If managed forest land, including sugaring operations and Christmas trees, should be excluded; and
    - If only certain geographic areas of the state or certain types of farms will be eligible based on available resources for the PES program.
- Farms should be allowed to enroll individual fields in the program and not be required to enroll their entire farming operation. However, the Working Group may want to consider requiring whole farm enrollment over time.

Quantification

- A modification of the Cornell Comprehensive Assessment of Soil Health (CASH) test may be the best option for quantifying soil health for this program. A committee of Vermont soil scientists and others will be needed to create the appropriate modifications, as described in this report, and the Task 1 Report.
- The CASH test is based on representative soil sampling from each field. Conducting soil sampling when fields are enrolled and then every three (3) years seems like an appropriate frequency to balance program costs with data richness.
- We strongly recommend that the Working Group devotes sufficient time to achieving a consensus on the issue of if and how to include biodiversity in the PES program or, at least, trying to reconcile the different viewpoints on this issue among Working Group members. A decision on this issue is essential before continuing program design efforts.

Payment Structure and Rates

- A hybrid payment structure in which farmers could earn a payment for (1) measured improvements in soil health from their farm's baseline, or (2) having a soil health score that is equal to or greater than a stated threshold may be the best way to incorporate fairness and additionality.
- Determining payment rates should consider both the costs to farmers and benefits to society of improved soil health.
- A public recognition component for farms that achieve the highest threshold of soil health should be considered. Such farmers could be recognized as "soil health heroes" and signage placed on the farm could indicate the resulting public benefits.

Monitoring and Verification

- If the program budget allows for it, it may be valuable to have the program cover the cost of third-party soil sampling for all participating farmers. This could increase farmer participation and result in more representative and consistent soil samples.
- It is probably not worthwhile to monitor practices on participating farms, since the program is most likely going to focus on the soil health score and not on the practices used. However, it may be valuable to make it very easy for farmers to report their practices on each field so they can be correlated with soil health scores on various types of soil.

Introduction

This report on program design issues and considerations for a soil health payment for ecosystem services (PES) program in Vermont is the primary deliverable from Task 8 of the project titled *Research Technical Services for the Payment for Ecosystem Services and Soil Health Working Group*. The intention of Task 8 (and this report) is to provide useful information to the Vermont Payment for Ecosystem Services and Soil Health Working Group (referred to in this report as "the Working Group") that can further their mission to design such a program.

This report starts with a discussion of the PES approach and clarifies the distinction between a focus on practices versus outcomes. This is followed by addressing the question of why focus on soil health. A short section then emphasizes the importance of clear and explicit goals and objectives. Some of the more important program design criteria are discussed next. This sets up an assessment of the specific, major program design issues to be considered by the Working Group. The report ends with a brief discussion of suggested next steps for the Working Group. The conclusions and a summary of the recommendations are contained in the Executive Summary at the beginning of the report and are not repeated at the end.

A set of three surveys solicited input from working group members on program design issues between December 2021 and February 2022. Survey results are incorporated throughout this report in subsections titled "Working Group Input". The verbatim responses to open ended questions from the surveys are shown in Appendix 1.

What is a Payment for Ecosystem Services (PES) Program?

Ecosystem services are the benefits to society that emerge from nature, including managed landscapes. There are many different forms of ecosystem services, but they are generally categorized as either being regulating, provisioning, supporting, or cultural. There is a plethora of information about ecosystem services in the scientific literature, as it has been an important concept in conservation over the past 25 years, including work emanating from UVM's Gund Institute.

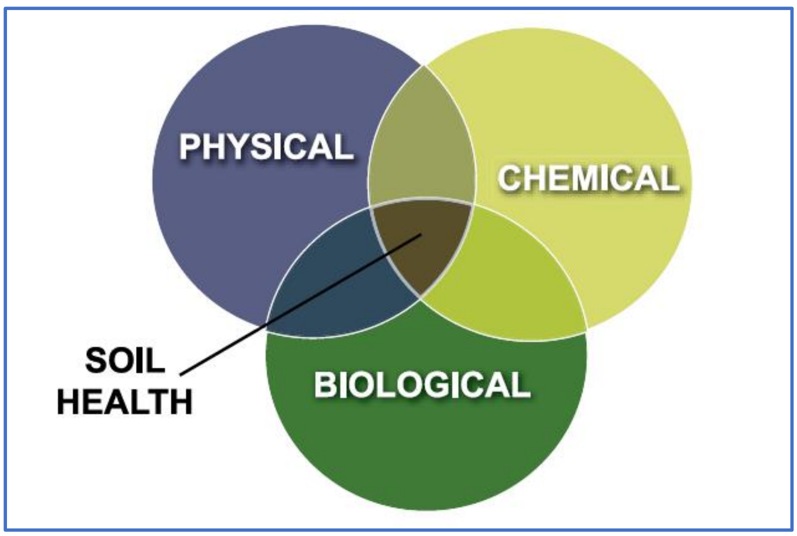
In a nutshell, ecosystem services are essential to address some of the most pressing environmental problems of our time, including climate change and water quality degradation. For example, carbon sequestration is crucially important to help to mitigate global climate change and the soil's ability to allow water infiltration and holding capacity is crucial to improve resilience to flooding and drought. Agriculture, because it covers such a large amount of land, is inextricably linked to these and other important environmental issues. However, a farmer's decision-making will most often not take these environmental consequences fully into account because the impacts and their associated costs rarely affect the farmer directly and exclusively. Rather, the costs are borne by people nearby, downstream, or globally. Such consequences are considered to be "external" to the decision-making process of the farmer and can be referred to as environmental externalities.

One way of addressing environmental externalities is with regulations. However, regulations on farming tend to be prescriptive, will often constrain farm profitability, and can be politically unpalatable. An alternative approach that is gaining increasing attention in the policy world is the concept of payments for ecosystem services (PES). The idea behind PES is to offer payments that motivate farmers to voluntarily make decisions that help to reduce specific environmental externalities resulting, in part, from their farming activities.

Payment for ecosystem services programs can pay for the implementation of specific farming practices (or the reduction thereof) or they can pay for specific outcomes. Paying for practices is generally easier to design and implement but paying for outcomes can be more effective and cost-effective. For example, paying for science-based reductions (i.e. measured or modeled) in nutrient loss from a farm's fields rather than paying farmers to implement one or more practices provides greater confidence in the environmental impact of a program. Further, paying for outcomes gives farmers more flexibility to achieve the outcome in a cost-effective manner, which can improve the overall cost-effectiveness of the program. However, designing a successful outcome-based PES program can be a complicated task. This report provides some description, assessment, and where appropriate, some recommendations for developing an outcome-based PES program focused on the improvement of in-field soil health on Vermont farms, as this is the charge of the Working Group.

There have been hundreds of PES programs implemented or tested throughout the world over the past 20 years. Salzman et al. (2018) reported that in 2018 there were 550 active PES programs with cumulative annual payments of over $36 billion. The focus of these programs varies, but generally fall into the following categories: water, carbon, and biodiversity (Salzman et al. 2018). A quick literature search did not reveal evidence of PES programs (current or past) that focus explicitly on soil health. Soil health is not an ecosystem service, but higher levels of soil health have the ability to contribute to several important ecosystem services, including climate regulation, climate adaptation, flood mitigation, resilience to drought, and improved water quality.

Figure 1. Venn diagram indicating the major facets of soil health.
Source: CASH Manual; adapted from Rodale Institute.



Why Focus on Soil Health?

As can be seen in the Figure 1, soil health is found at that intersection of optimized levels of chemical, physical, and biological aspects of the soil. The increasing focus within the conservation community on soil health in recent years seems to have significant merit. What distinguishes the focus on soil health from previous conservation approaches is that improved soil health has the potential to both produce a set of important ecosystem services and improve productivity and profits for the farm. If the farm becomes more productive, food security is improved. If the farm becomes more profitable through improved soil health, the field management changes that resulted in the improved soil health are not likely to be reversed if the PES program payments cease in the future. Conversely, if conservation field management changes reduce a farm's profitability, they are at risk of being reversed once the conservation program ends.

According to the USDA Natural Resources Conservation Service there are four primary principles to manage land for soil health[1]; these include (1) maximize the presence of living roots in the soil, (2) minimize soil disturbance, (3) maximize soil cover, and (4) maximize biodiversity. This report will not attempt to describe the intricacies of soil health or the many ways that it can be improved by Vermont farmers. For further reading on this subject there are numerous books, papers and reports available; a couple of relevant resources include Moebius-Clune et al. (2016) and Magdoff and van Es (2009).

The important aspects, relevant to this report, to understand are that there are many ways to improve soil health and that multiple field management practices are most likely required simultaneously. It has been proposed that there is a soil health "tipping point", which refers to the idea that once a critical threshold of soil health is reached, the rate of increased productivity also increases. Unfortunately, scientific research on this hypothesis is not evident in the scientific literature nor is information on that critical threshold clear or specific. There is some anecdotal evidence that simultaneous implementation of soil management practices in ways that adhere to the soil health principles can greatly increase farm profitability[2].

Program Goals and Objectives

In the design of any program, it is very helpful to have clearly stated and descriptive goals and objectives to start from. Inevitably there are difficult decisions that need to be made; decisions are facilitated by asking how each choice is likely to help achieve the program goals.

The Working Group was created by the Vermont Secretary of Agriculture as authorized in Act 83 of 2019. The announcement of the Working Group states:

"The purpose of this Working Group is to recommend financial incentives designed to encourage farmers in Vermont to implement agricultural practices that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters."

We encourage the Working Group to get even more specific with their goals for this program, as that will undoubtedly help the group to make important decisions necessary to design a successful program.

Program Design Criteria

Before discussing specific program design issues in the following section, it is worthwhile to consider some of the important program design criteria. The Working Group should give serious consideration to which criteria they feel are most important for the design of this PES program. Similar to the goals and objectives, having clarity on the relative importance of these criteria can greatly facilitate the group's decision-making process. The criteria discussed below are not an exhaustive list but are some of the more important ones to consider.

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[1] These can be found at the following NRCS website: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/soils/health/?cid=stelprdb1048783

[2] See interview with Rick Clark at https://regenfarming.news/articles/1348-us-farmer-interview-rick-clark

Cost-effectiveness and Efficiency

Regarding policy or program evaluation, these two concepts are similar but have different definitions. Cost-effectiveness is defined as achieving a given outcome with minimum cost. Efficiency is defined as maximizing the net benefits of the program, which is the total benefit minus the total cost. These definitions imply that a program can be cost-effective but not be efficient. The given level of outcome that is reached in a cost-effective manner (i.e. at minimum cost), may not be the level of outcome that results in the greatest net benefit to society. However, if a program maximizes efficiency, it will also be cost-effective. A program may need to achieve economies of scale in order to be efficient.

For the purposes of this report and the decisions in front of the Working Group, cost-effectiveness is a more relevant concept to consider in the near term. Outcome-based programs can have significant transaction costs (i.e. the costs incurred to allow the outcome-based payment to happen). Therefore, thinking about ways to reduce transaction costs will help to increase cost-effectiveness. Also, creating a payment structure and setting appropriate payment levels are crucial decisions that will affect the program's cost-effectiveness.

Cost-effectiveness has most meaning in a relative context; how would this program compare to other conservation programs? In order to have a measure of cost-effectiveness, one needs to know the technical effectiveness (i.e. outcome) produced by the program. Unfortunately, the vast majority of conservation programs are practice-based and do not quantify the outcomes produced. Therefore, comparing cost-effectiveness relative to programs such as EQIP, CSP, CRP, and CREP is not possible. Regardless, the designers and implementers of this PES program have a responsibility to attempt to maximize both cost-effectiveness and efficiency, at least within the confines of the larger program goals.

The issue of cost-effectiveness versus fairness is very important to consider. The Working Group has been very clear that it wants a program that does not disadvantage farmers who have already been making efforts to improve soil health and/or be excellent land stewards and conservationists. Therefore, the payment structure (discussed in the section on specific design criteria) is likely to include payments for existing high levels of soil health, as opposed to payments only for improvements in soil health (i.e. additionality). The latter would be more cost-effective, but the former is more fair.

There are several other important issues to consider regarding the program's cost-effectiveness which are related to the factors of human motivation. Motivation is defined as the act of goal-setting behavior. Humans generally have a drive to achieve clearly defined goals. Most of our federal and state conservation programs do not have such goals and have not been able to fully motivate large segments of the farm community. Three important features of goals include: specificity (clear and well-defined), appropriate difficulty (not too easy or too hard to achieve), and proximity (achievable in the not too distant future). Such goal-related features will need to be considered in determining the soil health thresholds that receive program payments.

The more flexibility that farmers have to achieve the goal, the more likely that they will be able to find ways that are least costly to do so. Flexibility can also harness the innovative capacity and problem-solving skills that farmers tend to be so good at; this can help to reduce total program costs.

A healthy amount of competition can motivate farmers to try to further increase their effectiveness (i.e. further improvements in soil health). Farmers, like all people, are interested to see how good their performance can get (i.e. part of intrinsic motivation), as well as if they can outperform other farmers (i.e. part of extrinsic motivation). Greater effectiveness, if it can be accomplished with less than proportional increase in costs, will increase cost-effectiveness.

Lastly, scale (i.e. farm size) can play an important role in cost-effectiveness. Larger farms may be able to achieve more cost-effective outcomes, although this is not necessarily the case. The Working Group may want to consider ways to ensure that smaller farms are able to fully participate in the PES program while recognizing the possible impacts on program cost-effectiveness in the face of budget constraints.

Financial Feasibility

For a program to be financially feasible the full costs of implementation and the budget constraints need to be known. Unfortunately, at the early stages of program design neither of these pieces of information are often very clear. As such, program designers need to assume that the program will face significant budget constraints and try to achieve program goals with minimum total program costs.

The three major categories of costs are program administration, payments, and quantification/verification. Program administration costs include items such as the salaries of managers and staff required to implement the program, as well as office space and supplies. The payments to farmers should be the single largest cost item and are discussed in the section on payment structure. An outcome-based program must have a way to quantify the outcomes on each participating farm. These costs can be borne by the program or by the famers. If the latter, the program payments need to be sufficient to leave the farmer better off from their participation. Verification of outcomes is also important in PES programs. For a soil health PES program, models could be used to estimate the ecosystem services that are produced from higher levels of soil health.

Assessing financial feasibility should include estimated total annual costs, risks of cost over-runs, as well as the potential to utilize debt instruments and to generate program revenue. Estimated annual costs should include all costs in the categories described in the previous paragraph, but some costs can be estimated with more certainty and precision than can other costs, such as program payments, which depend on the level of participation and effort by farmers. The ability to use subsidized loans to help implement a program that creates public goods (i.e. ecosystem services) may be possible, but that may require program revenue to repay. It is possible that credits for carbon offsets or water quality could be generated and sold to create program revenue. This is discussed briefly in the Program Administration section later in this report.

Feasibility of Implementation

Effective implementation is necessary to attain program goals. The program director or management team needs to have a feasible workplan that results in achieving program goals and they need the authority to make executive decisions required to keep the program on track. The program staff need to be well-qualified for their jobs and the program needs to be timely in its response to participants. Unfortunately, the staff who implement a program are not usually integrally involved in program design. The people who are likely to be program staff should be involved in program design; pilot-testing and adaptation should be considered part of the design process. Pilot-testing is the only way to adequately understand implementation problems and bottlenecks.

It is important that the implementation process does not end up obscuring the program's goals and objectives. For example, underestimating the amount of staff time required to process the information of each participating farm will either reduce the number of farmers who can participate or greatly increase the workload of the staff to the point where corners are being cut to save time. This can undermine the integrity of the quantification process and the reputation of the program.

The capability and enthusiasm of the staff in the administering agency is key for successful program implementation. Ideally, the program has one or more "champions" within the agency or entity. If the program is viewed as a burden to the agency or its staff, the probability for successful implementation will be decreased.

Program Compatibility – Relationship to Existing Conservation Programs

There are many existing conservation programs that offer payments to farmers. Most of these are practice-based, as opposed to outcome-based, programs (see previous section on PES programs for a description of the distinction). Programs are offered by federal and state agencies, as well as conservation districts and private sector entities. As the Working Group is already aware, it will be critical to design this PES program in a way that is compatible with existing programs.

Important questions to be addressed should include, but not be limited to, the following:

- How will this program be complementary to or in competition with existing programs?
- Are payments for outcomes from this program considered a "double dip" with payments from practice-based programs, such as EQIP?
- What comparative advantage will the program have for farmers and how can that be maximized?

Agency staff responsible for related conservation programs should be part of the stakeholder group that helps to inform the design of this PES program. Fortunately, most or all such agencies are represented on the Working Group.

Specific Design Issues for a Soil Health PES Program

Effective program design and pilot-testing are essential steps for a successful PES program. A science-based process with significant stakeholder input should be used to design the program. Regardless of how sound the program design is, careful pilot-testing is also essential, because using real-world situations is how many of the important questions are revealed. There are always unique circumstances on farms and questions from participants that provide opportunities for the program design to be modified according to science and stakeholder input. Program design should not be considered complete until pilot-testing has been done.

The major program design issues assessed for this PES program include eligibility, quantification, payment structure, and monitoring and verification. Each of these are discussed in the subsections below; each subsection presents some background and context, input from the Working Group, and recommendations. That section is followed by discussion of additional issues of relevance that, although important to consider, are secondary to those in the preceding section.

Eligibility for Participating Farms

Background and Context

The two important issues related to farmer eligibility for a program that offers the potential for additional farm income include (1) managing the program within budget constraints and (2) excluding farms that have violated specific societal expectations.

The issue of budget constraints can be more complicated than one might imagine when dealing with a program that will incur uncertain payment amounts due to lack of information on many factors. The primary uncertainties include how many farmers will enroll with how many acres, current levels of soil health, and the extent of improvements in soil health that farmers will achieve. Each of these factors will impact the program's payment obligations. The program must ensure that it does not over-commit and result in payment obligations that exceed funding available for payments. For this reason, a program may decide to start with a geographical or sectoral subset to allow eligibility from. For example, rolling out the program first in one watershed or for one type of farm, such as dairy. This approach to piloting the program could help the first phase run smoothly, but could create perceptions of unfairness.

There is a steep learning curve when implementing a new program; this is especially true for an outcome-based program such as this PES approach. Starting with a smaller focus can help the program to ensure adequate or exceptional delivery and evaluation, which will help to demonstrate the potential success of the program to other farmers, legislators, and the public.

Working Group Input on Eligibility

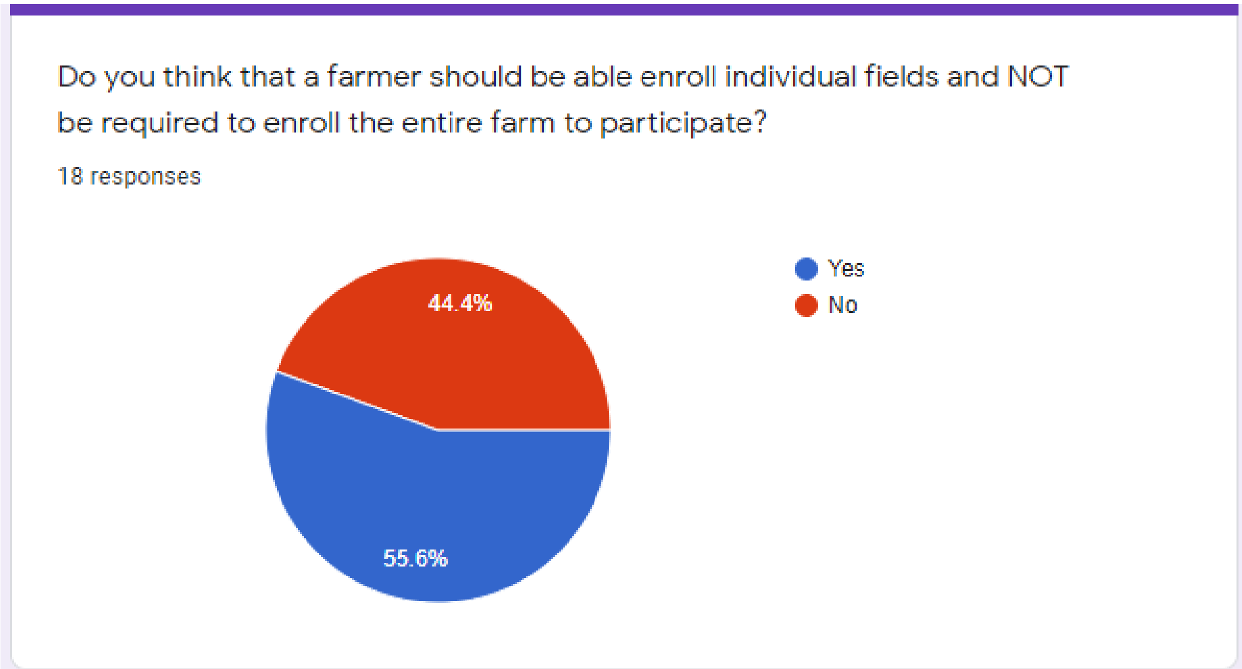
As part of the work of Task 8, we surveyed the Working Group (members and other participants) to understand their perspectives on various aspects of program design. We proposed a "strawman" program design to get the Working Group thinking about the relevant issues, including eligibility of any farm in Vermont that is registered as a commercial farm. This suggestion did not provoke any alternative suggestions. However, one respondent wondered what defines a commercial farm in Vermont. It turns out that the term "commercial" is not used by the State to define a farm. However, there is a set of criteria listed in Section 3.1 of the Required Agricultural Practices Rule. These criteria can be summarized as meeting any of the following: (1) the sale of at least $2,000 of agricultural products per year, (2) working at least 4 contiguous acres of land, (3) managing more than a certain number of livestock (varies by species), or submits a Form 1040(F) as part of their federal tax return.

Another issue related to eligibility (as well as other program design issues) is whether farmers should be able to enroll individual fields or should be required to enroll their entire farm in the program. The input from the Working Group (18 responses) related to this issue indicates that 56% of respondents think that farmers should be able to enroll individual fields and 44% think that the enrolling the whole farm should be required (Figure 2). This can be seen in the pie chart below. Based on the open-ended feedback from the Working Group, this issue seems to come down to some members preferring a holistic approach to farm management, while others feel that it will be easier for farmers to enroll and less costly for soil sampling to allow individual fields to be enrolled.

Allowing individual fields to be enrolled may help to increase farmer participation due to requiring less time and effort by the farmer. An idea that was stated by more than one member is to allow individual fields to be enrolled but require that the whole farm ultimately be enrolled within some number of years.

The Vermont Required Agricultural Practices Rule defines the important aspects of society's expectations for the minimum level of acceptable land management. Farmers who are not in compliance with the RAPs could be considered to be violating these expectations. Given that the vast majority of Vermont farms are in compliance with the RAPs, it would likely be seen as unfair to the majority to allow farms to participate in this PES program who were not in compliance with the RAPs.

Figure 2. Survey results on enrolling individual fields vs entire farm.



There were 12 responses to the open-ended question: "If you have any other input related to eligibility, please state it below." The verbatim responses are shown in Appendix I. Below are a summary of the responses:

1. Would be good to make sure that eligibility criteria excludes backyard gardeners and other non-farmers.
2. Suggestions to allow enrollment of individual fields, but have a requirement to enroll whole farm within a certain period of time.
3. Requiring enrollment of the whole farm could:
    a. diminish experimentation and innovation because it would be too costly to do this on whole farm.
    b. be problematic for diversified farms, as there may be parts of the farm operation for which it does not makes sense to enroll.
    c. be more consistent with a holistic approach to management and that may be a desirable outcome.
4. The CSP+ proposal (which was presented to the Working Group as a path forward) focuses on comprehensive planning with the help of technical service providers (TSPs); it may be okay to enroll just some fields if the whole farm is being considered in the planning process.
5. The Glastir program (Wales) which was reviewed as part of Task 6 of this project requires that all land enrolled in the program be under full management control of the enrolling farmer for at

least the duration of the program contract (5 years). This requires tenants to prove their control of rented fields to be enrolled.

6. At least one respondent was concerned with the potential for “leakage” without whole farm enrollment. Leakage is when improvement is made on one parcel but is partly or wholly negated by detrimental management other parcels.
7. There were concerns that requiring whole farm enrollment could reduce potential participation.

Recommendations on Eligibility

1. All farms in the State of Vermont should be eligible to participate, provided that they are compliant with the Required Agricultural Practices and in good standing with the State.
    a. The working group should consider whether the eligibility of forest land should be excluded. It seems that a sugaring operation would meet the definition of a farm by the State. However, sugaring operations could result in very large program payments which do not provide “additional” ecosystem services.
2. Individual fields should be able to be enrolled, at least initially, in order to increase farmer participation. Encouraging or requiring whole farm enrollment over time could be considered. The Working Group would need to decide if and how woodlots, sugarbushes and other non-field parts of the farm were included in the program. It seems that soil health in these areas would be on a different scale than in-field soil health and may be better to exclude them from the program.

Quantification of Soil Health

Background and Context

Soil health is complex and there are many (i.e. dozens or scores) metrics that are used in combination to define soil health. There are several possible approaches to gauge soil health, including soil measurement (i.e. sampling and analysis), simulation modeling, or an approach based on the field management practices used over time. For many PES-type programs, a measurement approach is not practical. A pertinent example for Vermont is the new Pay-for-Phosphorus program which pays farmers for modeled reductions in phosphorus (P) loss from their fields. To measure P loss, which is very diffuse across the landscape, would require monitoring equipment that is far too costly to justify on a per field or per enrolled farm basis. Most existing conservation programs are practice-based; experimental outcome-based programs most often use simulation modeling.

Although it may be more practical and cost effective in some cases, modeling can be problematic for several reasons. First, the models may have inadequate accuracy, high level of uncertainty, or insufficient precision in estimating the environmental outcome (e.g. P loss from any given field). This can undermine the ultimate environmental outcomes of the program, as well as confidence in the program. Second, the flexibility of the farmer to affect the outcome is limited by the types of practices that are built into the model. Third, running most models can take a lot of time and data, which can drive up the transaction costs of the program.

COMET-Farm is a well developed modeling tool that can estimate carbon sequestration and greenhouse gas emissions outcomes for PES programs. However, COMET-Farm does not model other soil health parameters or other ecosystem services beyond climate regulation. To our knowledge, an appropriate model does not exist which captures indicators of all the ecosystem services of interest to the Working Group.

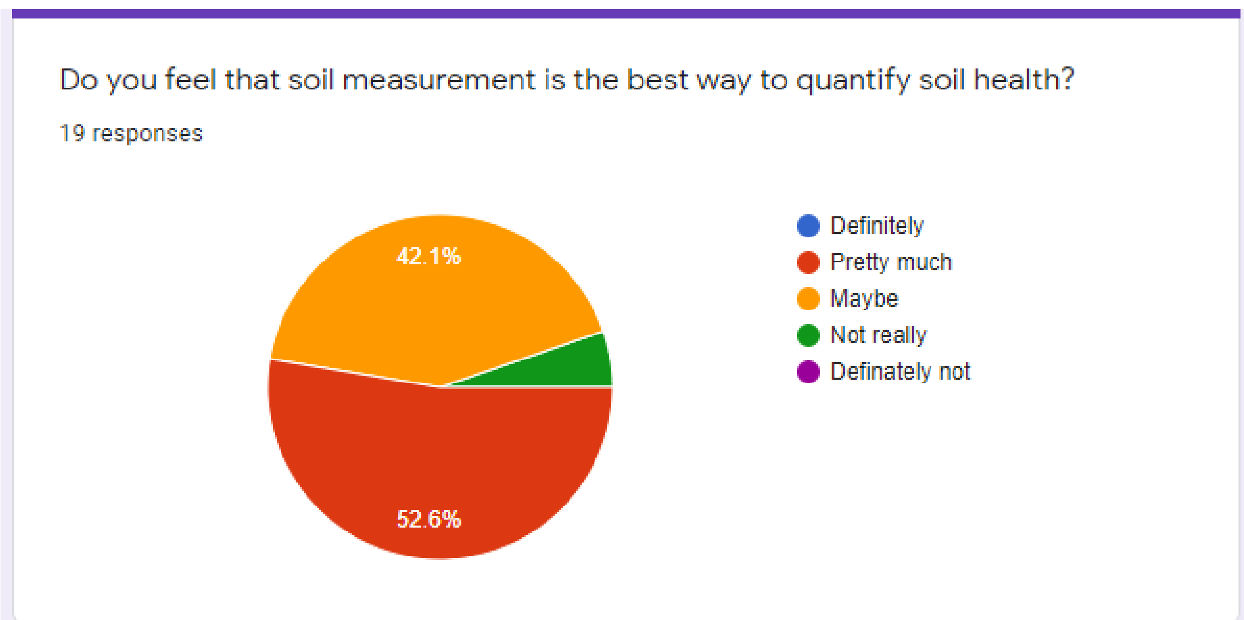
The PES program under development, with a focus on soil health, has the potential to use a measurement approach to quantification because it may not necessarily be prohibitively expensive to secure adequate soil samples and perform the necessary analyses on them. Measurement may drive transaction costs, and overall program costs, but the measurement approach creates almost unlimited flexibility for participating farmers to try to achieve desired outcomes. An important exception would be if farmers use soil amendments that are considered to be undesirable and/or detrimental to increase their soil health scores; specific program rules would need to be developed and made clear to participants.

It should be noted, as discussed earlier, that soil health is really a proxy for the ecosystem services desired by the public. However, for the farmer, soil health has tangible private benefits which can increase net farm income. Ideally, the incentive payments motivate farmers to make changes to improve soil health and the private benefits are what prevents farmers from reverting those changes if the program ends.

Working Group Input on Quantification

The survey results from the Working Group indicate that that a slim majority (53%) feel that soil measurement is "pretty much" the best way to quantify soil health, with most of the remainder of respondents indicating "maybe" (Figure 3). No respondents indicated "definitely" nor "definitely not" and few responded, "probably not". This indicates that soil measurement may be the best path forward, but that more information and education on the quantification options may be necessary.

Figure 3. Survey results on soil measurement.



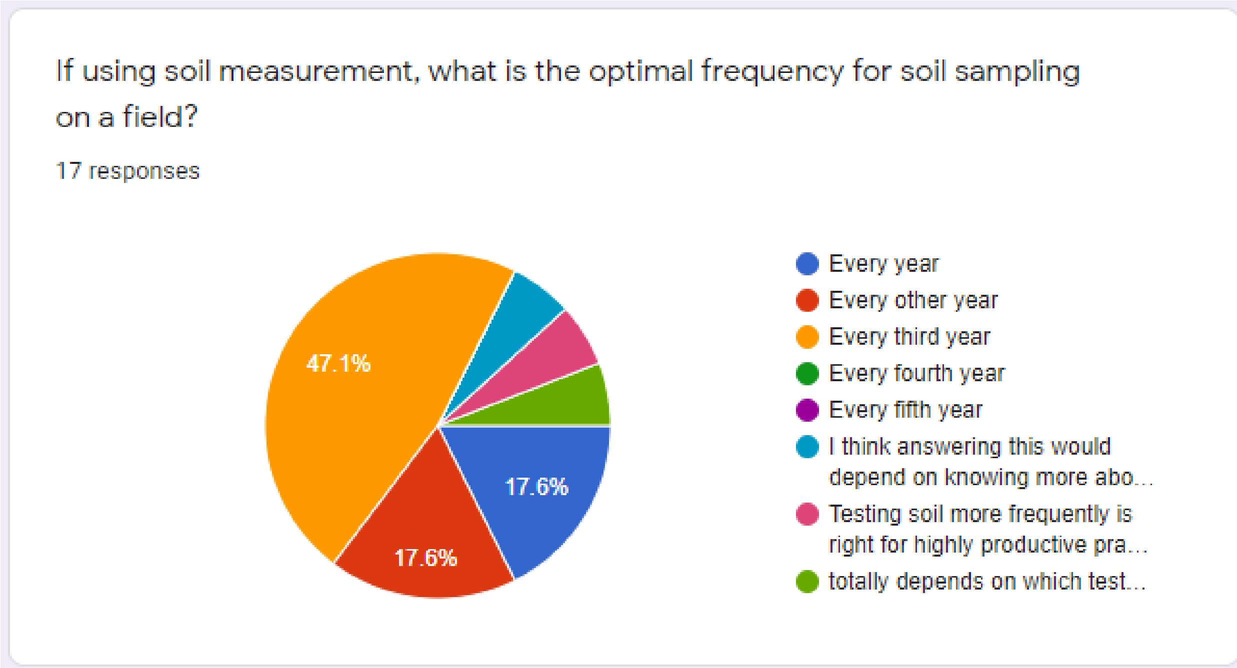
There were 13 responses to the open-ended question: "If you have other suggestions for how to quantify soil health, please explain them below. Other options could be (1) estimating soil health based on field management practices or (2) some type of simulation modeling." The verbatim responses are shown in Appendix I. Below are a summary of the responses:

1. Many respondents indicate that soil measurement is their preferred approach; saying that they think it is simple and straight-forward but need to be aware of the time lag between field management changes and measurable changes in soil health.
2. Should prioritize measures that farmers can accurately and affordably do on their own, including observations. There are on-farm observations that are results of soil health, such as yields, produce quality, herd health, biodiversity, etc. that could be used.
3. Would like to see more of a holistic quantification that includes biodiversity, water infiltration and holding capacity, wetlands, pests and pathogens, reduced runoff, erosion, and off-farm inputs.
4. Would like to see a combination of soil measurement (including deeper than 30cm), as well as a focus on practices, possibly with some modeling. One response indicates that more than just soil measurement may be needed to be able to tell the full story of the ES being produced.
5. Several respondents indicate that monitoring the quality and quantity of practices is important and perhaps a better approach to quantification for this program. It was said that:
    - Monitoring practices is already being done for other efforts, so this may be an easy way to quantify soil health.
    - Practices may be a good way to get payments to farmers sooner than waiting for measured soil health to change.
    - Measured results could be used to trigger augmented payments.

If soil measurement were going to be used, almost half of the respondents (47%) think that soil sampling every third year would be optimal (Figure 4). About 18% each think that every other year or every year is preferable. The survey results from this question can be seen below. The more frequent the soil sampling, the more information is gathered and the more costs are incurred by the program. However, the important questions from a program design perspective include:

- Will the additional information, given that changes in the soil can be slow, be worth the additional cost of more frequent sampling and analysis?
- Will more frequent soil sampling requirements reduce the participation rate by Vermont farmers?
- Will less frequent measurement adequately account for interannual variability in soil measurements?

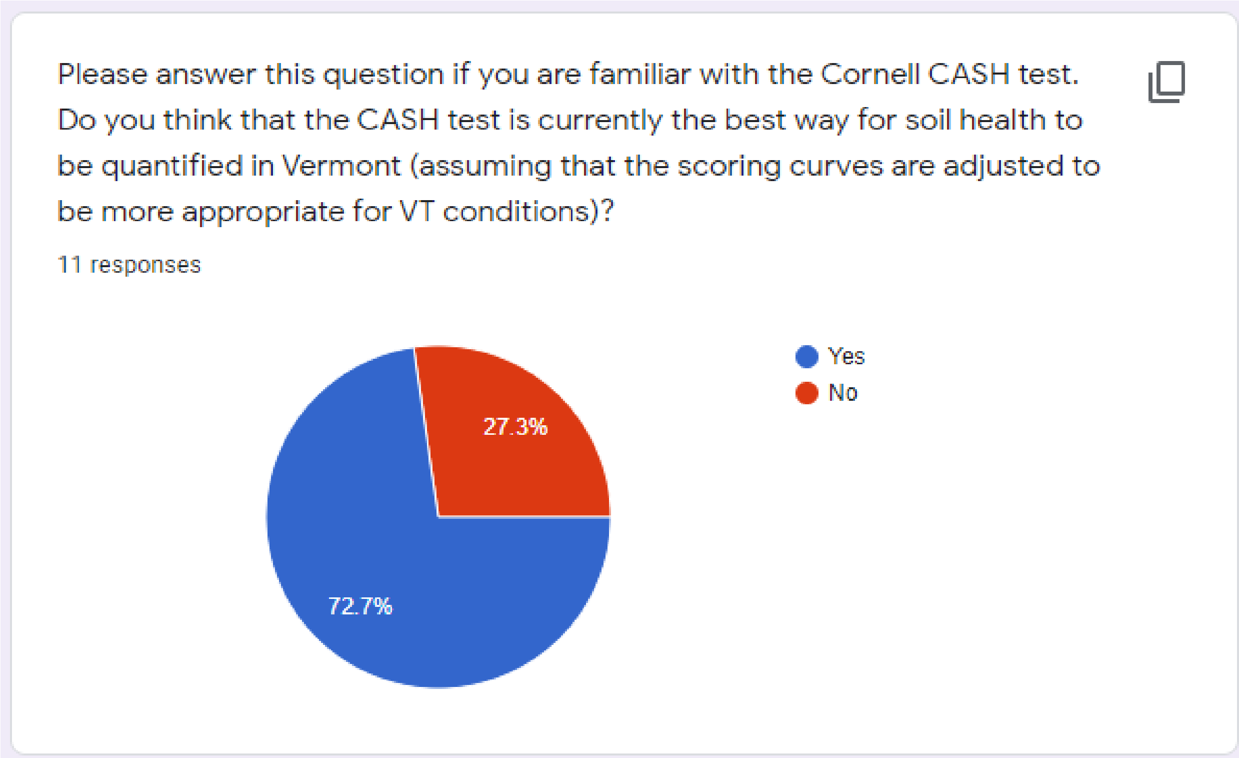
Figure 4. Survey results on optimal frequency for soil sampling.



Information on the Cornell Comprehensive Assessment of Soil Health (CASH) test was presented to the Working Group in 2021. The CASH test is a tool that has been developed by Cornell scientists and others over the past 10+ years to help farmers and researchers quantify soil health. It has been used recently in Vermont as part of the Vermont State of Soil Health project and the Vermont Environmental Stewardship Program (VESP). This has revealed a need to modify the scoring system to make the CASH test more useful in Vermont. The survey asked respondents to indicate if they thought that the CASH test, provided that they were familiar with it, was the best way to quantify soil health. Almost 73% of respondents indicated yes and 27% indicated no. This tool is discussed in more detail in the following subsection (Figure 5).

It is important to note that the CASH test was not developed for the purposes of an incentive program. It was developed as an educational tool for farmers to understand soil health on their fields. Hence, there are several important modifications to the CASH test that would be necessary for use as a quantification tool in an incentive program. These are also discussed in the next section.

Figure 5. Survey results on use of CASH test.



The Cornell Comprehensive Assessment of Soil Health and Its Use in Vermont

The CASH test, as described above, is a comprehensive soil analysis consisting of many metrics related to the physical, chemical, and biological properties of the soil. More information, including the full manual describing the background and metrics can be found here.

There were 10 responses to the open-ended question "Are there other tools or means for quantifying soil health that you want to suggest? Please explain your suggestion with some details." The verbatim responses are shown in Appendix I. Below are a summary of the responses:

1. Several respondents indicate that they think the CASH test, with necessary modifications, is the best approach to quantification.
2. Several respondents emphasize the importance of including biodiversity at several levels, as well as other landscape functions such as water infiltration and those provided by wetlands.
3. It was suggested that there are observations and proxy measures, such as habitat, soil armor, paddock rest periods for grazing systems, and presence of trees and shrubs that should be considered as part of the quantification system.

Working Group Input on Biodiversity

The inclusion of biodiversity metrics in this program may be the most difficult issue that the Working Group has to navigate currently. Our team issued a survey on this subject to collect thoughts and input from the Working Group and the interested observers. There were a total of 14 responses; the results are summarized below.

There are contrasting opinions regarding what the intentions of the Working Group are with regard to biodiversity. The Working Group leadership has indicated that if any biodiversity metrics are to be included, that they should be within the soil. Alternatively, some members of the Working Group have expressed their views that broader field or landscape-level biodiversity is very important to include.

As can be seen in the chart below (Figure 6), 57% (8 respondents) indicated that including biodiversity in this PES program is “extremely important”, which equals a score of 10 on a scale of 1-10. One respondent indicated 8 and another resonded 6 out of 10. Three respondents were neutral (5) and one indicated that including biodiversity is not a good idea. In terms of the types of biodiversity that Working Group members think should be included are wildlife habitat/diversity (11), plant diversity (11), soil microbial diversity (10), and soil macroinverstebrates (9) (Figure 7). The number of votes is shown and the % of respondents voting for each is shown in parentheses in the chart. There was also one vote each for these write-in answers: pollinators and root diversity.

From the open-ended question asking for further thoughts on the inclusion of biodiversity, the responses can be categorized into two major themes. One theme is the importance of overall ecological function related to farming and that associated landscape-level biodiversity needs to be included in the program. For example, one response indicates that wildlife habitat is the form of biodiversity that is most closely aligned with the mission of the Working Group and this PES program. The other theme is that the focus of the Working Group is soil health and, therefore, any biodiversity metrics should be within the soil. One response indicates that soil microbial diversity and the presence of macroinvertabrates is the type of biodiversity most closely aligned with soil health and that soil health is the stated focus on this PES program.

Figure 6. Survey results on including biodiversity in the quantification.

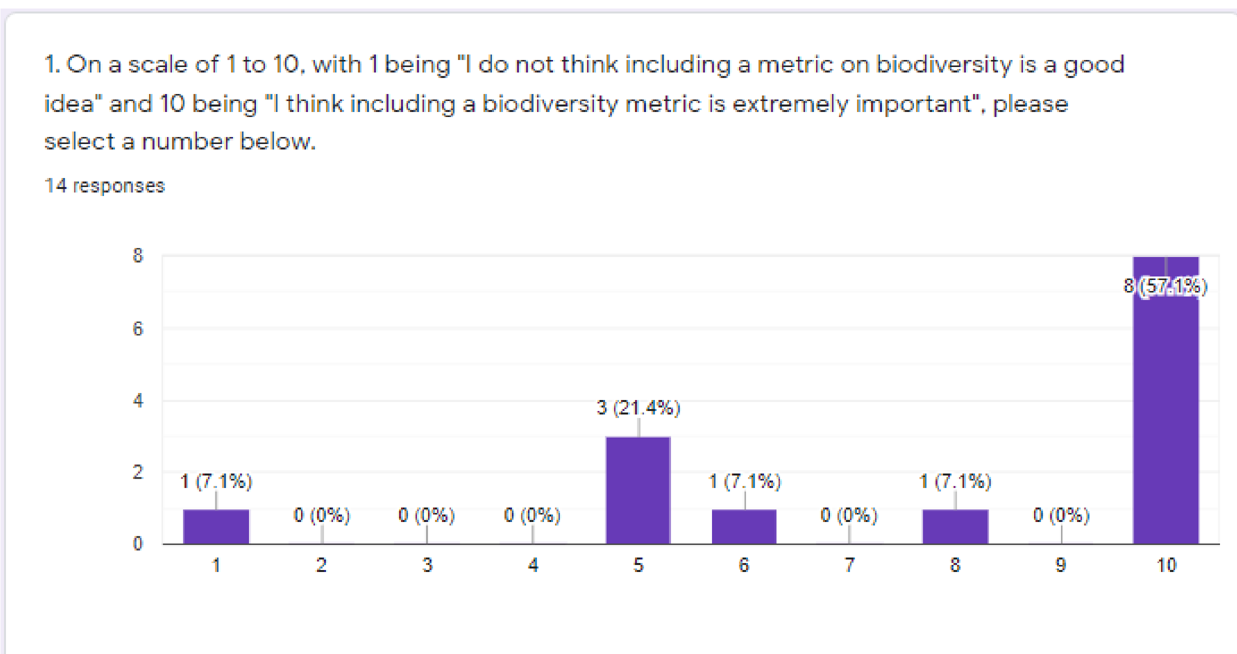
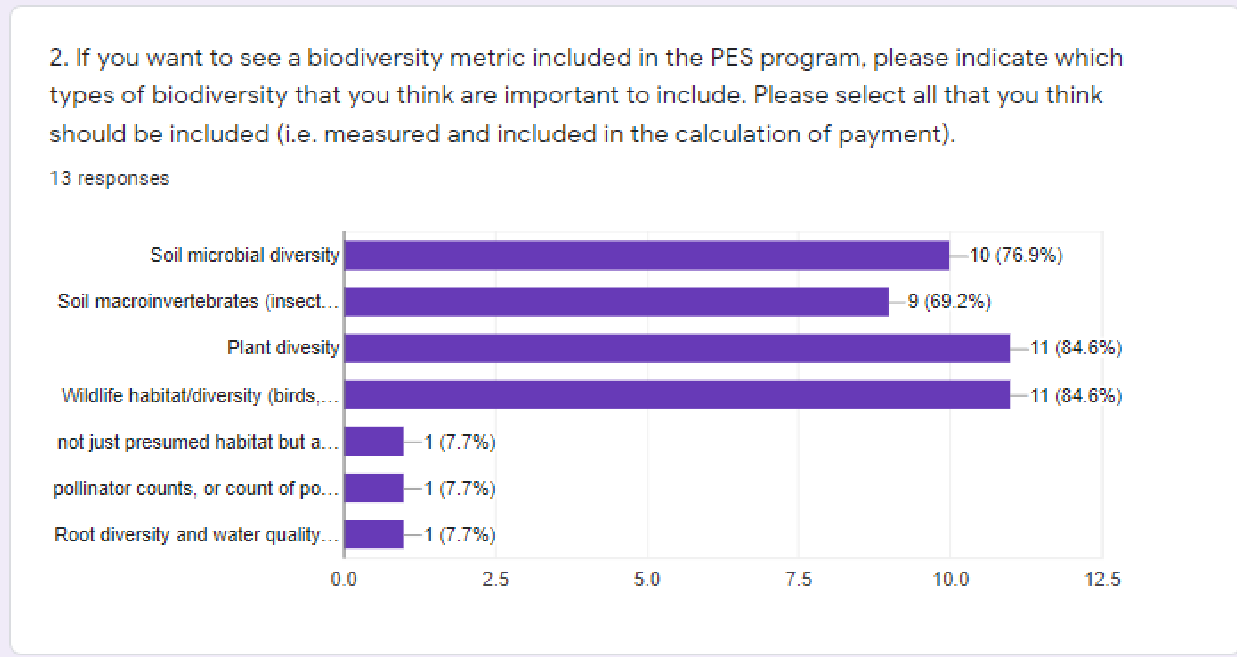


Figure 7. Survey results on the types of biodiversity metrics to include.



Recommendations on Quantification

Our recommendations on quantification for this PES program include the following:

1. The CASH test offers a structure that could be modified to be more useful in Vermont and for this PES program. The primary areas of modification that have been identified so far include:
    a. Assess which measures that are included in the CASH test should be kept and which should be discarded or replaced with an alternative. For example, adding a lab test for soil bulk density would be much more useful than the penetrometer reading that the CASH test currently uses as a proxy for bulk density. However, the lab test would add additional cost to the quantification process; the cost-benefit ratio would need to be assessed.
    b. Adjusting the scoring curves used in the test to be more appropriate for Vermont soils. As noted above, Vermont soils tend to score quite high on average using the CASH test. This may make it difficult to detect improvement in soil health that the PES program would like to incentivize.
    c. Ensure that the soil types are adequately factored into scoring curves to level the playing field across farms. This issue is also related to the previous item about adjusting the scoring curves for the included measures.
    d. The CASH test currently uses an equal weighting of all of the many measures to create a soil health score. The weighting of included measures to produce an overall soil health score should be addressed by a committee of Vermont soil scientists (see next recommendation).
    e. A committee of Vermont soil scientists should be formed to assess the measures to include, the weighting, and the overall scoring curve with a goal of adapting the current CASH test to be most useful for the goals of this Vermont PES program.

2. Create a template for calculating a farm's weighted soil health score. Each field will have a modified CASH test score as described above. The score of each field and the respective number of acres would be used to calculate a farm's weighted soil health score. The payments could be calculated field-by-field and then summed up, but it may be simpler to create the weighted score and use that to calculate the farm's payment. Either way, each farmer should be provided with their field-specific scores, including the results of each measure within the modified CASH score. This will allow each farmer to make informed decisions on the best strategies to increase each field's score and on which fields they can most cost-effectively increase their overall farm score.
3. We strongly recommend that the Working Group devotes sufficient time to achieving a consensus on the issue of if and how to include biodiversity in the PES program or, at least, trying to reconcile the different viewpoints on this issue among Working Group members. Some further issues to consider include:
    a. The CASH test includes a test of microbial activity, but does not include a measure of diversity. In 2021, UVM Extension initiated its first state-wide effort of soil microbial diversity analysis on farm fields using EcoPlates (produced by Biolog). If soil microbial biodiversity were to be included, the EcoPlates would be a likely candidate for quantifying this. However, at a cost of $30 per sample and lack of evidence of correlating benefits, it is not clear that soil microbial biodiversity should be included. If this is to be pursued, we recommend that a committee of Vermont soil scientists (mentioned above) assess all feasible means for quantifying soil microbial diversity and how to appropriately weight this in an overall soil health score, or leave it out.
    b. The inclusion of aboveground biodiversity in this soil health focused PES program will add further complexity to the program and possibly reduce the feasibility of implementation. PES programs are complicated; a key to success is to keep the program as focused and simple as possible. We encourage the Working Group to give serious consideration to how inclusion of biodiversity could impact the program's success.
    c. If the charge of the Working Group is improved soil health, than any biodiversity measures included in this program should be closely related to soils and soil health. Soil microbial and invertebrate diversity are closely related; diversity of birds or plants on the farm are less related and may be better targets for a different incentive program.

Payment Structure: Additionality vs. Fairness

Background and Context

The issue of additionality refers to whether the incentive payment produces "additional" improvements in soil health (and by extension in ecosystem services) that are not already being delivered based on how the fields are currently being managed or would not be delivered in the absence of the payment. Some farmers have been very active conservationists for decades and other farmers have done very little conservation. For the former group there will be less opportunity for further cost-effective improvements in soil health (due in part to the law of diminishing returns). For the latter group, there may be plenty of low-hanging fruit (changes that can improve soil health with little or no additional cost). If budget constraints did not exist, additionality would not be a crucial issue.

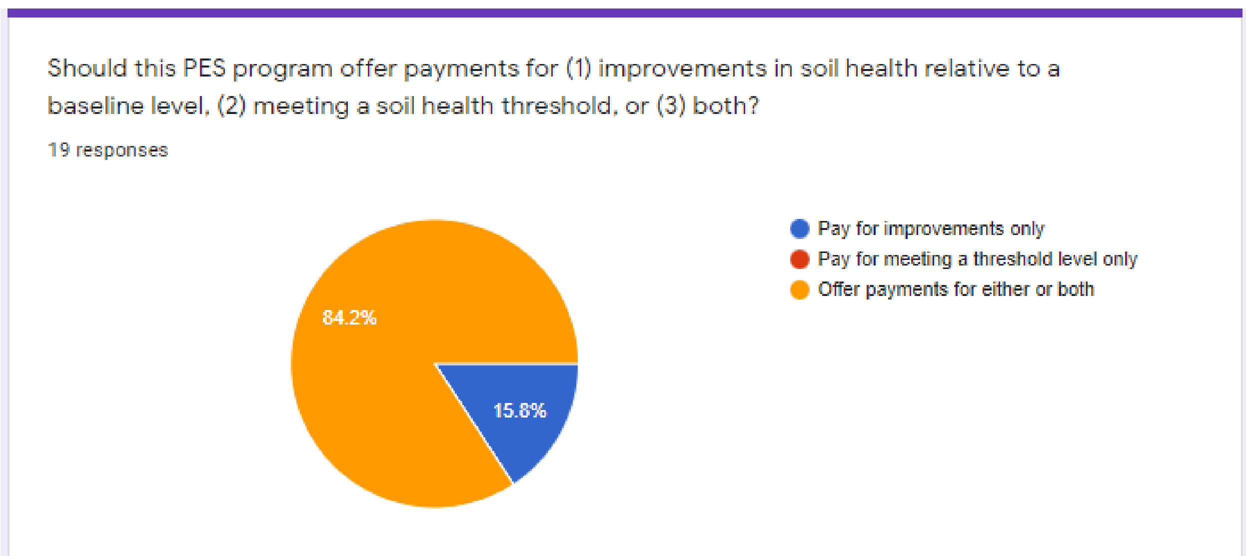
Put another way, it is not fair for farmers who have made efforts and incurred costs to manage their fields for improved soil health to be penalized (i.e. disadvantaged) relative to farmers who have not made such efforts. However, the cost-effectiveness of the PES program will be greatly diminished by paying for soil health that has already been delivered (i.e. non-additional). This is an ever-present policy issue that does not have a "right" and a "wrong" solution; it requires careful consideration of program goals, as well as current and future budget constraints.

From the first meetings of the PES Working Group in 2019, there has been a stated intention that the program be fair to farmers who have been early adopters of soil health practices. However, the Working Group also has some members who are very concerned about the potential cost of this new program relative to the available financial resources for it, if any. Further, a program that is paying farmers with public dollars, but is not securing "additional" ecosystem services could be hard to sell to the public. Ideally, this PES program will be both cost-effective and fair. The recommendations below are an attempt to meet both goals.

Working Group Input on Payment Structure

As can be seen in Figure 8 below, 84% of survey respondents indicated that offering both types of payments is preferable. In some situations, farmers could earn payments for both improvements and for meeting the threshold simultaneously. However, for higher soil health scores further improvements may become more difficult to achieve. The verbatim responses to the open-ended question on payment structure are shown in Appendix I.

Figure 8. Survey results on payment structure.



Recommendations on Payment Structure

The design of the program's payment structure is the place where the additionality vs. fairness issue can most directly be addressed. We recommend:

1. The Working Group should consider a hybrid payment structure in which farmers could earn a payment for (1) measured improvements in soil health from their farm's baseline, or (2) having a soil health score that is equal to or greater than a stated threshold. For the soil health improvement, the payment amount would be a function of the increase in soil health score, the payment rate per point, and the number of acres enrolled. For exceeding the threshold, the

payment amount would be a function of the number of acres and the payment rate per acre. Establishing a series of thresholds with an increasing payment rate per acre should be considered.

2. With regard to baselines:
    a. The baseline used for improvement should be the soil health score at the time that the farm was enrolled in the program or at the previous program quantification for the farm, whichever was most recent. As such, if the program requires soil measurements from each field every three years, then the baseline for improvement would be reset every three years.
    b. The concept of a baseline is not applicable to the threshold payments. At any given quantification period either the farm exceeds the threshold, or it does not.
3. The template for the weighted farm score (see quantification recommendations) can be used to calculate payments for either improvements or exceeding thresholds or both.
4. With regard to payment rates:
    a. The payment rates for improvement should be set to be great enough to motivate most farmers to want to increase their weighted soil health score. The minimum end of the range of payment rates could be informed by the full economic costs to the farmer of making management changes to improve their soil health score. Refer to the Task 4 Summary Report for an evaluation of full economic costs. The maximum end of the range could be informed by the full social value of the resulting ecosystem services. Refer to the Task 5 Summary Report for an estimate of these social values. The chosen payment rate would lie somewhere within this rather large range and be dictated by the program goals and budget constraints.
    b. The payment rates for exceeding soil health thresholds should be set to acknowledge the value of the benefits that maintaining healthy soils has for the public, but not be set so high that the program costs exceed available funding for it.
    c. Setting appropriate payment rates will require research (and/or existing data) that can correlate changes in field management with improvements in soil health score and incorporate information on the costs of field management changes and benefits of improved soil health scores.
5. Including a public recognition component for farms that achieve the highest threshold of soil health. Such farmers could be recognized as a “soil health hero” and signage could indicate the resulting public benefits.

Monitoring and Verification

Background and Context

There are several aspects of monitoring and verification for a PES program that should be considered. These are addressed below and followed by some suggestions and recommendations.

<u>Monitoring field management</u> – Based on the adage that “the proof is in the pudding”, if this PES program is based on soil sampling and analysis, then it may not be necessary to also monitor field management. However, improved soil health will require improved field management and it may be beneficial for the program to collect information on existing and new field management. Collecting this information could help justify the program cost to the public and it would also help by providing information on which changes were most effective on which soils over time. This

information could be very valuable for participating farmers over time and help other farmers make informed decision on which practices to implement and where for the biggest impact. Management information could be voluntarily submitted by farmers for this purpose. It may not be necessary to monitor or verify field management practices, if the payments are not a direct function of the practices, as opposed to a function of the resulting soil health scores.

Verifying soil sampling protocol – For accuracy of soil measurements it is essential that soil sampling for each field be representative of that field. Farmers know very well where in each field the best soils are. It would be easy to take samples that over-represent those areas and thereby skew the field's soil health score. Most farmers would probably not do this, but self-sampling opens the door quite wide for biased soil samples. It is possible that each soil core in a sample can be geo-referenced to show its location and the distribution of core samples across a soils map of the field. However, the probability that all farmers will have access to this technology in the near term is low and it does not prevent the ability to cheat. An addition, it would take staff time to verify that samples were randomly collected or collected from representative locations.

Alternatively, using objective third parties to take the soil samples may be the best way to ensure representative sampling. However, this will add more cost to the program, whether paid for by the program or by participating farmers. It is possible that the efficiency of sampling done by trained professionals could reduce the overall costs of sampling. This could also help to assuage fears of cheating. Working group members have suggested a peer sampling program could lower costs by allowing participating farms to have their samples collected by another farmer, using the food safety program as a model.

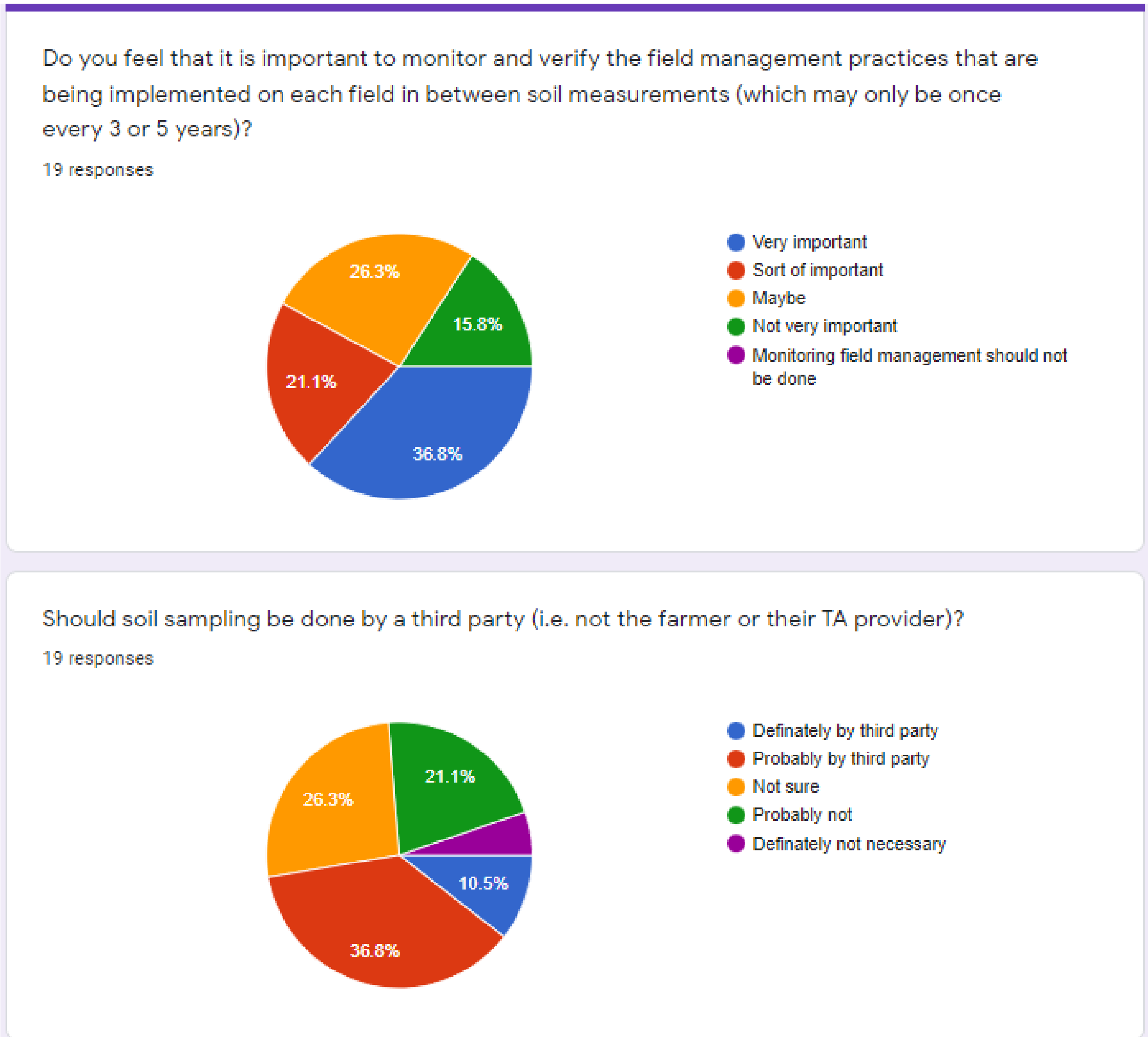
Verifying soil test results and CASH score calculations – It should not be necessary to verify lab results, as any trusted lab that the program chooses will most certainly provide objective results. The calculation of the modified CASH scores for each field will presumably be done by program staff and will be objective and correct. Double-checking results, calculations, and payments should be part of a quality assurance, quality control process for the program.

Working Group Input on Monitoring and Verification

As can be seen in Figure 9 below, there was a wide variety of perspectives on both monitoring of practices and third-party soil sampling. Over 57% of respondents thought monitoring of practices was either "very important" or "sort of important". Over 26% indicated "maybe" and 16% indicated "not very important. No respondents indicated that this practice should not be done. In retrospect, it may have been better to ask this and other questions in the context of likely budget constraints faced by the program.

With regard to requirements on soil sampling, 47% indicated that it "definitely" or "probably" should be done by a third party. Just over 26% indicated "probably not" or "definitely not" and the remaining 26% were "not sure". These results indicate that most lean toward third-party sampling, but also a smaller contingent lean away from it.

Figure 9. Survey results on monitoring and who does the soil sampling.



Recommendations on Monitoring and Verification

1. It is not recommended that the program monitor practices on enrolled fields, as this will increase the administrative costs of the program, thereby taking resources away from incentive payments. Since the quantification of soil health is based on soil measurements and not contingent on the practices used, the benefits of monitoring practices seem unlikely to justify the costs of doing so.
    a. However, the PES program should make it as simple and easy as possible for farmers to voluntarily submit details on the practices implemented in each field over time. Although not used for monitoring, this information will allow the program to better understand the connection between practices and performance on various soil types and make this information (adequately aggregated) known to farmers throughout the state. It may be worth considering a small bonus payment to farmers who provide this information.

2. If the program budget allows for it, it may be valuable to have the program cover the cost of third-party soil sampling for all participating farmers. There are several reasons that we recommend this approach:
    a. It may increase farmer participation in the program by making it easier for farmers to enroll.
    b. It will likely result in more representative soil samples, as well as more consistency and fairness across the program.
    c. It may be more efficient and cost-effective from an overall resource perspective to have trained personnel taking the soil samples because they will have the experience and equipment to get the sampling done relatively quickly.
    d. It may enhance public support of the program by eliminating an obvious source of potential cheating.

Additional Issues of Relevance:

Program Administration

Background and Context

Two important administrative issues related to a program such as this are the selection of the implementing entity (i.e. responsible for program implementation and success) and the configuration of the program structure (i.e. components and dependencies). There are many possible configurations for administering a soil health PES program in Vermont. The questions that should be considered in such a decision include:

1. Is there adequate trust between farmers and the program administration to not hinder farmer participation in the program?
2. Are there "champions" in the administering body who are committed to seeing this PES program succeed?
3. Are there strong working relationships among the entities who are contributing to and/or responsible for the program's success?

Regarding #1: Any PES program will require a certain amount of farm data to be shared with the program. Some farmers are leery of government and are reluctant to share any information that they think can be used against them under current or future regulation. Such concerns may be more prevalent for programs that are estimating P loss from the farm than for a soil health PES program. If compensation levels are adequate, farmers may be willing to participate and share data even if they harbor some distrust. However, all else being equal, the greater the level of trust by farmers of the program and its administration, the greater the level of farmer participation.

Regarding #2: If the implementation of this program is saddled on to an agency that does not want to administer it or does not have staff who are enthusiastic about it, the program may not get the attention and level of effort that are required to make it successful. A PES program, which has a level of complexity, could have a shared administration. This is addressed in the following point.

Regarding #3: An agri-environmental PES program should have the buy-in of the agricultural and the environmental communities. Bridging the historical divide between these two constituencies is a very important consideration that can help to secure resources for a new program. If there is shared administrative responsibility for this program, it is important that there be good and functional working relationships between the two (or more) entities, starting at the highest levels, but also between the staff doing the work.

A recent USDA-funded Conservation Innovation Grants (CIG) project proposed the idea of a Vermont Soil Health Trust as a construct to advance soil health on Vermont farms. A summary of this idea is shown in Figure 10 below. The PES program being designed by the Working Group could fit into this structure under the "Outcomes Fund". Instead of paying for carbon and for water quality, it could pay for soil health. However, if the program plans to sell carbon or water quality credits, it will need to quantify those outcomes specifically.

Recommendations on Program Administration

There has not been any significant discussion in the Working Group devoted to the issue of program administration to date. However, the program would benefit from co-design by the staff and agency that will administer the program. There are elements of program administration that are crucial for program success. The recommendations below address these elements.

1. Ensure that program administration and/or oversight has representation from both the farming and environmental communities.
2. Ensure that the entity and staff administering this PES program are enthusiastic about the program and optimistic or determined to achieve the program's goals. Having a champion on point for program coordination is helpful.
3. Consider the pros and cons of implementing this PES program within a larger context such as that described above as the Vermont Soil Health Trust.

Program Costs and Potential Sources of Funding

Background and Context

As with program administration, there has not been a lot of focus yet on program costs. Some discussion of potential sources of funding has started and at the time of this report being drafted, the Governor's proposed budget for FY23 included $1 million for this program. A program needs to have an initial design before its costs can be estimated. However, clarity on the potential sources of funding, associated levels of funding, and probabilities can be helpful in tailoring the initial design toward something that is feasible.

An alternative approach is to create the initial program design without regard to funding sources and budget limitations. This represents an "if you build it, they will come" approach (from the movie Field of Dreams) and can be an instructive exercise, even if the reality of budget constraints ultimately requires significant paring. Discussion in the Working group have touched on both approaches.

The general categories of costs to implement a PES program include (1) administrative costs, (2) incentive payments, and (3) quantification and verification costs. A program that can achieve its goals with lower administrative and quantification/verification costs will have more funds to devote to incentive payments, which are designed to motivate participation and change.

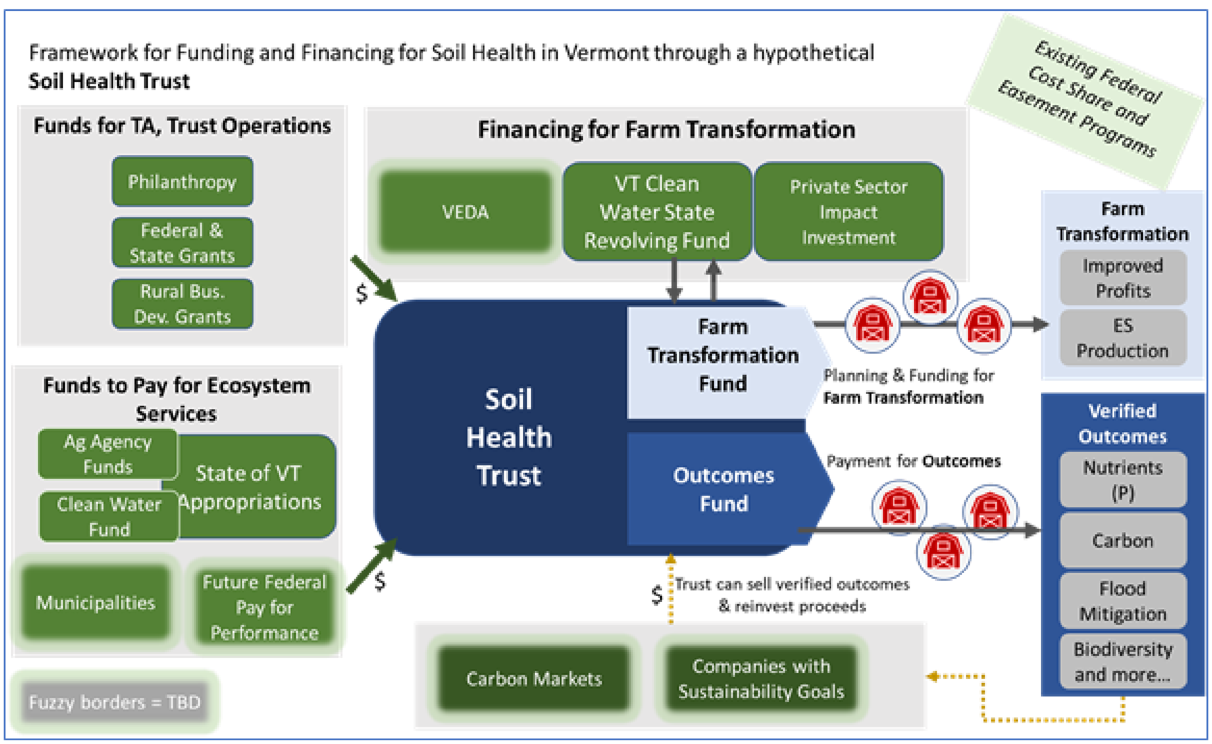
Figure 10. Conceptual framework for a VT Soil Health Trust; produced by a separate project.

Vermont Soil Health Trust - Summary

To help build and maintain a healthy farm sector in Vermont, the Trust would 1) provide the financial and technical support that farmers need to design and implement a pathway to regenerative agriculture and 2) facilitate ES payments to farmers for quantified environmental outcomes. To achieve both of these, the Trust would operate two related funds:

- **The Farm Transformation Fund** would provide interested farmers with the financial and technical assistance (TA) resources necessary to transform to regenerative agriculture. A TA team of agronomy, dairy/livestock, and farm finance experts would work with each farmer to develop a farm transformation plan. Each farm-specific plan would contain estimates of productivity and financial performance, as well as ES generation. Improved profitability and divestment of unnecessary equipment would free up cash for new investment, if needed. Debt restructuring may be necessary for some farms. The projected flow of ES could be used to determine financing terms and to justify public investment in the transformation.

- **The Outcomes Fund** would implement one or more pay-for-performance (PFP) programs that provide the framework, metrics, and tools to quantify the relevant ESs and pay farmers for what they produce. The Outcomes Fund would aggregate carbon and water quality credits and market them through all available channels. Revenue from credit sales would augment the Outcomes Fund to be able to reward more farmers for environmental outcomes.



The recent Soil Health Trust CIG project mentioned above also assessed potential funding sources for advancing a soil health PES program in Vermont. A report titled *"Funding and Financing Resources for Vermont Farmers Interested in All-in Soil Health and the Delivery of Ecosystem Services"* was completed in May 2021 and is available as a resource for this project. Figure 11 contains a brief summary from that report.

Figure 11. Potential funding and financing sources identified for Vermont Soil Health Trust.

Type of Funding	Program/Agency/Player
Funding for adopting Soil Health Practices	• Cost Share: USDA: EQIP, CSP, RCPP; AAFM: FAP, BMP, GWFS; RD: REAP. • Clean Water Fund Grants for Agriculture: VHCB Water Quality Grants, AAFM Capital Equipment Assistance Program • Water Quality Financing (Clean Water State Revolving Fund)
Direct Payments for Environmental Outcomes or Ecosystem Services	• Public Programs: RCPP PFP (Phosphorous Reduction), VT Environmental Stewardship Program • Private Programs (ESMC, Indigo Ag, Carbon Markets, Supply Chain Programs) • *Non-VT Case Study: Soil and Water Outcomes Fund (Iowa) and Brandywine-Christina (Chesapeake Bay)*
Financing for farm transformation to regenerative systems	• NGO's: High Meadows, Taproot, Castanea, VT Community Loan Fund • DBIC • VLT/Farmland Futures • USDA-FSA Conservation Contracts • Traditional financing (easements, FSA, Farm Credit, VEDA, VACC, WLEI loans) • *Non-VT Case Study: RePlant Capital*
Other sources of capital	• Rural Development Grants and Programs (Value-Added Producer Grants, Rural Business Development Grants)
Technical and Business Planning Assistance	• USDA, UVM Extension, VHCB, AAFM

Vermont Agriculture and Food System Plan 2021-2030 includes a Food System Financing Inventory. This is a listing of capital providers who help to finance farm and food businesses, including debt, equity, and royalty financing, as well as various grant programs. The inventory is a supplemental document to the Vermont Agriculture & Food System Strategic Plan 2021-2030 as requested by the Vermont Legislature as part of Act 83/S.160 (2019). It can be found here. https://www.vtfarmtoplate.com/resources/food-system-financing-inventory.

Working Group Input on Potential Sources of Funding

To date, the only input on potential sources of funding solicited from the Working Group has been from staff of the Vermont Agency of Agriculture, Food, and Markets (AAFM) and the Vermont Housing and Conservation Board (VHCB) since they are more closely connected to the legislative process and state-level funding sources. Although there is no crystal ball to know what funding may be available for this PES program, the following has emerged.

1. Direct funding allocation for piloting this PES has been proposed in the Governor's FY23 budget at $1 million, but is uncertain if it will be in the final budget.
2. It may be possible that funding from the state's Clean Water Initiative could be used for this program. Similarly, tapping into funds from the state's Water Quality bond should be investigated. Similarly, tapping into funds from the state's Water Quality bond should be investigated. Legislative changes may be required for use of these funding sources for this PES program.
    a. Both of these would require establishing a very clear scientific link between the soil health metric used by the program (e.g. a modified CASH test score) and improved water quality, which has not yet been proved to be consistently correlated.
    b. Most of the conservation practices that increase soil health are the same practices that are funded through water quality programs, such as EQIP, so there should be some correlation.
3. A significant amount of funding has been provided to the state through the American Rescue Plan Act (ARPA). It is possible that these funds could be tapped into for this PES program. However, ARPA funds are short-term and targeted more for infrastructure or job creation. As such, these funds are not likely to fit a soil health program.
4. There is funding being allocated to the implementation of the newly created Vermont Climate Action Plan. It has been suggested that the more clearly that the climate co-benefits of this PES program can be demonstrated, the more likely that a portion of the state's climate action funding could be used.

Recommendations on Potential Sources of Funding

The sources of funding for this need to be fully investigated once there is a draft program design. We recommend that the Working Group leadership form a funding subcommittee for this purpose. The subcommittee should include agency staff who are very familiar with the legislative and funding process in Montpelier, but it should also include at least one farmer and one person representing the environmental groups. These members will help convey the breadth of commitment and support that this program has.

Assistance to Farmers – Technical and Financial

Background and Context

Outcome-based programs benefit from farm-level planning and assessment to produce information that can aide in farmer decision-making related to field management to maximize benefits from the program. It would be very valuable for participating farmers who are trying to improve their soil health scores to achieve a higher threshold to receive technical assistance and information for decision-making. However, staff time is expensive and can drive up the total program costs quite quickly.

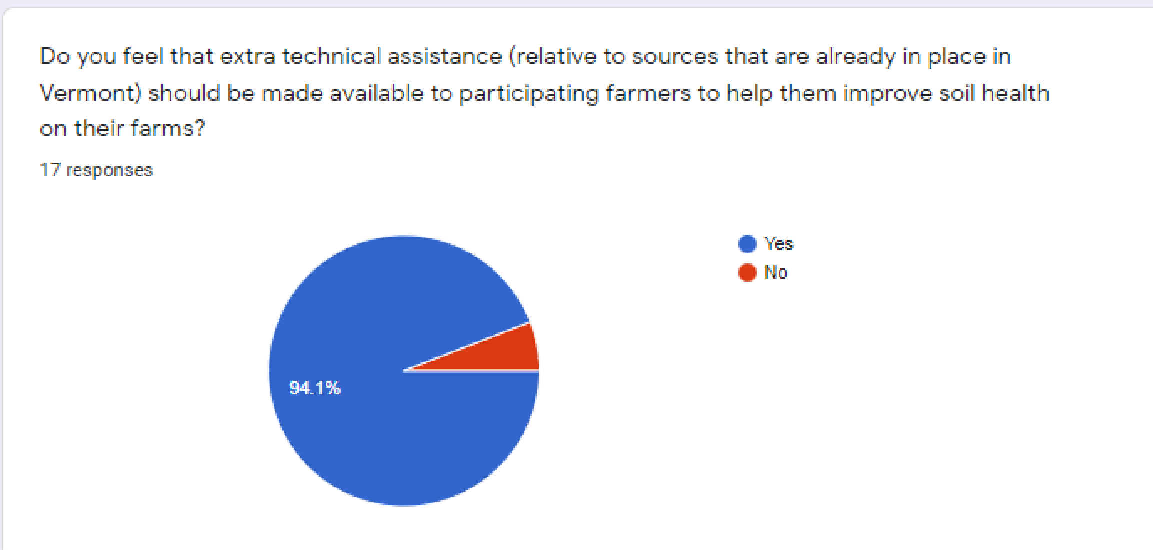
TA resources can be found in Vermont within federal and state agencies, UVM Extension, Conservation Districts, and in the private sector, but it seems that TA resources are tighter than they have been in the past. Even if TA is provided by an agency at no cost to the PES program, all staff time has a cost and needs to be accounted for in the total economic cost of the program.

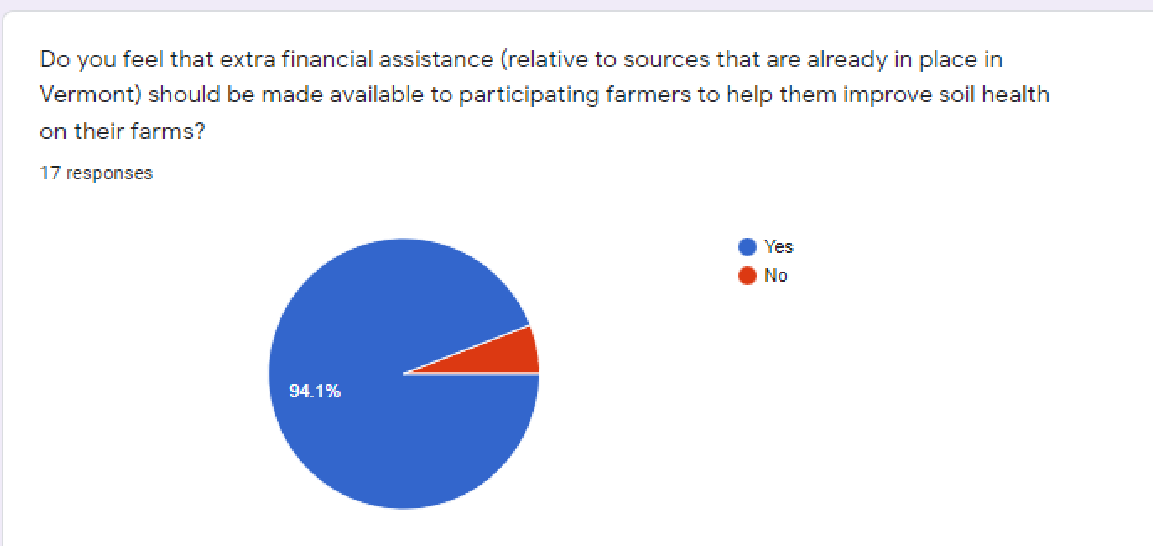
Financial assistance, in addition to the outcome-based payments earned by farmers through the program, can take the form of cost-share or other program payments for conservation practices from federal and/or state sources. USDA policy allows farmers to sell environmental outcomes (e.g. carbon and/or water quality credits) even if they have received practice-based payments for implementing conservation that resulted in the environmental outcome. Similarly, cost-share funding from existing programs should be encouraged to help farmers improve soil health and allow them to benefit from this PES program.

Working Group Input on Technical and Financial Assistance

Relative to the current amount of technical and financial assistance available to Vermont farmers, our survey asked Working Group respondents to indicate if they felt extra technical and extra financial assistance should be made available to farmers who participate in this PES program to help improve soil health on their farms. As can be seen in Figure 12, over 94% of respondents indicated that additional technical and financial assistance should be made available to PES program participants. This result is not surprising.

Figure 12 Survey results on supplying additional technical and financial assistance to participating farmers.





Recommendations on Technical and Financial Assistance

Additional technical and financial assistance are a function of available resources, which change over time and cannot by fully known in advance. At this early stage, what can be said is that more help to farmers to improve their soil health is consistent with the PES program goals and would be advantageous. Encouraging interested farmers to take full advantage of related cost-share programs could help boost their soil health scores in this program.

Program Evaluation and Adaptive Management

It is important that the evaluation of a program be carefully considered during its design. Successful evaluation is essential for program improvement over time, which is enabled through an adaptive management approach. This is another reason why clear and specific program goals and objectives are essential. The evaluation should be able to indicate not only if the program's implementation is working well, but if it is meeting its goals and objectives.

Key performance indicators need to be identified during the design process and continuous or periodic data collection of required variables is necessary. The types of variables that are likely to be useful for the evaluation include farmer satisfaction, staff time (including sampling and technical assistance) required, administrative costs, farmer payments (for both improvements and meeting thresholds), as well as all the soil health metrics and estimates of the ecosystem services produced. Going through the exercise of creating an evaluation report before the program is launched can be extremely useful to identify the specific information needed and how best to collect it.

Using an evaluation specialist during the design process can pay dividends for the program by creating efficiencies in data collection, analysis, and reporting. This can be invaluable for a new public-funded program that needs to justify its impact and cost-effectiveness to legislators and the public. Additionally, designing an adaptive management process that utilizes the results of each evaluation to modify the program and/or its delivery is necessary to ensure improvement over time.

Suggested Next Steps

A summary of this report including the recommendations are provided in the Executive Summary. This section provides a brief description of the suggested next steps for the Working Group to effectively and successfully design a soil health PES program for Vermont.

1. ***Articulate clear goals and specific objectives*** for this PES program. Clearly stated goals and objectives will be of critical importance in making decisions about specific program design issues. As choices need to be made by the Working Group, each alternative can be evaluated based on how well it will help to meet the goals and objectives of the program.
2. ***Create a program design subcommittee*** tasked with pushing the design process forward. The full Working Group is probably too large to effectively and efficiently dig into the plethora of details and decisions that are required for a program as complex as this one. This subcommittee should include Working Group members who represent the differing perspectives on issues such as the inclusion of biodiversity and holistic management, as well as the cost of the program and perceived budget constraints. It should also include staff who are likely to be involved with or responsible for program implementation.

3. ***Enlist a program evaluation specialist*** into the program design process. Specifying exactly how the program will be evaluated and determining its critical success factors as part of the design process will result in a stronger program with a much greater likelihood of success.
4. ***Create a program funding subcommittee*** to inventory and assess the potential funding sources for this specific PES program. Information generated by this subcommittee will be very useful in determining if the program being designed is financially feasible or not.
5. ***Assemble a team of Vermont soil scientists and others*** to suggest modifications of the CASH tool for use by this PES program. It is fairly clear that (1) the CASH test may be the best basis for quantifying soil health in this program, and (2) that the CASH test will need some modifications to be effectively used for a program like this in Vermont. Getting started on these modifications as soon as possible will help the program design process.
6. ***Seek resources to advance research*** that (1) correlates field management (and changes thereto) with soil health scores and (2) calculates the full economic costs to the farmer. A greater understanding of which types of field management is most effective at increasing soil health scores on which soil types and at what cost will provide important information for farmers across the state. This information will help farmers to find the most cost-effective ways to improve their soil health performance.

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Appendix I – Verbatim Responses to Survey Questions

Verbatim responses related to the question: *If you have any other input related to eligibility, please state it below.*

I think a farmer should be able to start out by enrolling individual fields with the goal of enrolling the whole farm, maybe by X year to encourage whole farm ecological health.

Participation in in baseline soil testing

Any landowner should be able to enter into the program for any amount of acreage. I'd like to see continued participation require more acreage added each year until the whole farm/forest/orchard is included. Whole farms that are participants, no matter the size, should receive an annual base income for their service to society. Additional financial incentives should pay for practices to implement and reward for performance on an annual basis. Practices that do not yield desired performance should not cost the land manager money nor should performance rewards be administered.

I don't have a response to this question at this time. I haven't thought a lot about this specific question or talked about it with farmers. An immediate thought is that allowing a farm to choose some fields and not others may not necessarily reflect their management - rather the state of the field at that point in time given whatever history of management has or has not occurred on it... this seems selective, and to favor farms with more land to pick and choose from. If we are wanting to ensure that farms (as full entities) are improving their practices / outcomes, etc. - then it would seem to me that we may want to look at the entire amount of land being managed (and potentially other costs not directly seen on the land / in the soils: pesticide manufacture and usage, transportation and supply chain, habitat connectivity, etc.).

1) For an outcomes based program that does not prescribe practices and emphasizes farmer autonomy and ingenuity, I think a whole farm requirement would be prohibitive for farmers who want to test out new approaches without making an experiment of their entire farm (I'm not sure this would matter in a practice based program as much because it would be less experimental), 2) Diversified farms might want to enroll some management areas of their farm, but not all (ie, someone producing both beef and vegetables my want to enroll their pastureland but not vegetable fields. I had a similar experience working on a farm that produced mixed livestock and had a vegetable csa--it made sense to certify the vegetables, so we did, but we would have lost money certifying the livestock, so we would not have been able to certify the vegetable CSA organic if we were required to certify the entire farm.), 3) regarding the concern that a farmer who can enroll individual fields may exploit unenrolled fields to balance costs lost for enrolling other fields, I'd like to draw attention to the approach of the CSP+ program--in the proposal, we hadn't settled on whether a farm would be able to enroll only individual fields or not. However, one thing we discussed when drafting that proposal was that the main emphasis of the CSP+ is the comprehensive planning element with TSP. In this approach, its possible a farmer could only enroll some fields on which to sell services, but the comprehensive plan could account for the entire farm to ensure that services weren't being produced in some areas at the expense of others. 4) several people have raised the concern about how to handle leased land

for whole-farm enrollment. The main program I recall from the Task 6 review that considered that problem was the Glastir program in Wales, and you can find their enrollment requirements here at page 5: https://gov.wales/sites/default/files/publications/2018-01/glastir-entry-2015-rules-booklet-1.pdf

My other input would be "it depends" on individual situations. Sorry for the confusion!

Concerns with making improvements in one area could be negated on other farm lands

I feel it would be too limiting to require farmers to enroll their entire farm, so I am in favor of allowing enrollment of individual fields.

Checked "no" above because I am an advocate for a holistic approach wherein participating land managers would undertake Soil Health Management Systems to transform all practices on the farm towards the goal of carbon farming and maximizing restoration of landscape function and biodiversity.

There has to be a lower limit on acreage or that true agriculture being practiced on the property

I believe that the whole farm aproach should be used

I would be hesitant to enroll land that may be rented on an annual basis, and would rather invest inputs into owned land, or land that has a longer term lease. This is especially important if the payout is based on farm average. In another scenario, a sandy field might not do very well across a farm average. While it can still be managed quite well, I am not sure how the proposed metrics would rank it. Until we get some ground truthing done, the per field basis seems less risky to to the farmer. I am wondering what the term commercial means? I think it is anyone selling goods? May need to define a field, Id say tree farms could be eligible, if the they were cultivated/planted. I would not be apposed to this as they seem to meet the programs objective and allow for some creative approaches to rank well.

Verbatim responses to the question on quantification: *If you have other suggestions for how to quantify soil health, please explain them below. Other options could be (1) estimating soil health based on field management practices or (2) some type of simulation modeling.*

It seems like this may not be a single solution situation. For properties of soil health that can be accurately and affordably measured, especially by farmers themselves, we should do that. Ideally we can help support some research that could help more accurately calibrate farmers' field observations to specific outcomes so that the easily accomplished, on-farm tests and observations farmers conduct can be reliably extrapolated to tell us what is being accomplished.

Bear in mind how long it can take for soil health changes to manifest after a grower changes practices (sometimes 3-5 years)

I see the value of soil measurements and like the idea of a VT-type CASH test but would like to find a way to monitor changes over time that yield a whole systems perspective to include increased biodiversity in flora and fauna, increased water infiltration and holding capacity, improved wetlands, reduced pest/pathogen pressure, reduced off-farm inputs, reduced run-off and erosion...

This depends on what is being measured, how it's being measured, etc. I think there needs to be a combination of direct measurement (ideally at a substantially greater depth than 30cm - or measures to greater depth in addition), as well as assessments of outcomes based on management practices, and potentially some modelling (for example, a 30cm soil core is not going to tell the story of how the canopy of agroforestry plantings slow rainfall or increase transpiration, or even how the roots of the trees, shrubs, and perennial forages affect soil qualities to a reasonable depth, or the increased habitat these multiple horizons bring; a 30cm soil core is not necessarily going to tell the full story of a biodiverse well grazed pasture with a high residual and how that transpires, slows water movement across the landscape, provides more habitat, etc.). This is a case of "both / and" vs. "either / or" to me. We want to be accounting for and encouraging the most progressive and impactful practices which help the greatest number of farmers, and their human and non-human communities - and we need to be able to meet people where they are to get there.

Is there a reliable and economic option? Practices can't be a measurement, only a first, logical step toward a measurable goal.

Quantification is an important first step. Modeling can be calibrated based on extensive measuring and quantification. Estimating soil health based on field management practices can be vague and inaccurate

Best determined by agronomists but prefer over modeling. Only other consideration should be looking at the field mgmt practices -we are already tracking so many of those for P reductions that it would be far more efficient to track for soil health improvement as well (and for ghg reductions)

It is not practical to measure carbon sequestration, water quality and other enhanced functions on every farm every year. Therefore UVM should continue to conduct trials and monitor pilot farms to establish median averages resulting from the implementation of soil health plans. Farmers will be expected to document practices. Because of the many variables of farm context, and the long-standing adverse economic environment for farmers in general, I am an advocate for upfront rewards for adoption of healthy soil practices, which may be augmented upon regular demonstration of quantifiable results of said practices. Soil health can also be measured in observation of yield and keeping quality of produce, health and balanced production of livestock, levels of landscape functionality and biodiversity on farm.

I think measurement over time is critical. I think crop yield/ crop health and farmer observation are important. I also think the health of pollinators, beneficial insects, birds, microbes, soil arthropods, etc. are also important indicators of soil health. Hard to measure but I think worth trying to capture somehow here. I would be curious to learn what option #1 above looks like.

Management History/Nutrient management combined with comprehensive soil "health" quantification in real time, not just modeling.

Modeling preferred

The soil test seems to be the most accurate, efficient way and it covers a lot of the discussion points that group has had since its inception. I like the simplicity. I like that I could potentially enter the data in GIS software to create a heat map, and see how its impacting other data sets, or how those maps are impacting the soil health map. This is an area were funding outcome rather than practices becomes incentive to do a better job with practice.

Plant health, biodiversity (insects, birds), nutrient density of crops all also good.

Verbatim responses to the question on use other quantification tools: *Are there other tools or means for quantifying soil health that you want to suggest? Please explain your suggestion with some details..*

I think CASH, plus some additions would work well

increased biodiversity in flora and fauna: species counts using gps, a transect grid, simple observation hoop and a pencil. Great to partner with schools, citizen scientists or youth groups

increased water infiltration and holding capacity: I understand that bulk density and SOM are indicators. Using transects and infiltration rings on site is telling.

improved wetlands: upland and lowland, livestock exclusion zones, incentives to bring back beavers, uphill swales, riparian buffers, and other agroforestry practices

reduced pest/pathogen pressure: leaf analysis, nutrient availability, soil and whole plant microbial diversity

reduced off-farm inputs: incentivize making compost, compost teas, plant-based foliar sprays, cover cropping

reduced run-off and erosion: take photos in spring and fall, measure water quality downstream

There are traditional tools of observation and relationship for judging the ecological values and outcomes on a landscape as well which are used by farmers, service providers, particular programs, and others such as: diversity of species present, presence of a diversity of horizons of habitat (pasture, shrub, water surface, tree, pollination), length of residual remaining after haying or grazing, rest period length in grazing between rotations (in relationship to greater grazing plan, etc.), presence of trees and woody shrubs appropriately managed in a pasture landscape, amount of land with intensive soil disturbance and land left without effective soil cover, very short farm-table "footprint", solid manure management vs. liquid manure management, etc. I think that many of these broader pattern and outcome observations are important, as they speak to a diversity of outcomes which soil measurements may not and may not take into account: from habitat and hydrological cycles, to slowing the movement of water across the surface of a pasture, to emissions considerations.

Via quantifying soil microorganisms, soil respiration, structure, infiltration, aggregate stability, bulk density, etc.

yes above with the caveat of the adjusted curves. But defer to agronomists

Working with a TSP advisor (or team) land managers can record and demonstrate how the 5 principles of soil health (developed by the NRCS----6 if you count context) are being applied in all aspects of land management. For instance, a market gardener uses a combination of mulching materials, cash crops, and cover crops to ensure that soil is "armored" at all times. If the land manager is enrolled in a Soil Health Management System (could be CSP+) the onus on will be to keep records on how principles are being translated into practice according to the specific farm plan. This would be a master plan subject to revision and similar, but more ambitious in scope, to a Nutrient Management Plan.

As above--I think tracking yield and crop health over time is an important indicator of soil health (and aligns with a farmer goals).

Biological Diversity & numbers. Fungi is important too! Also consider at what depth in the soil profile you are measuring & quantifying.

CASH alone does not get to all the data I believe is needed and desired

Verbatim responses related to payment structure: *If you have any other input related to payment structure, please state it below*.

My answers to the last two questions are based on a limitless budgets scenario. There are are a lot of practice-based programs that can help farms make the changes they need to improve soils health. And of course we'd love to have more TA for all farms.

I left both blank, because I'm not sure. The single test seems pretty simple. I think if the payout rate is adjusted to reflect the work being done and the the cost of the sample data, then there would be money to hire services or keep additional funds on the farm. The question with this approach becomes are there enough private means to get this done. Some public employees, do not do much boots on the ground work, and i have heard at our meetings that there is some desire to be in the office less and out in the field more. This would seem to be a healthy transition for those staff members. Adding it to the payout structure also adds an element of accountability, as you will want to recoup your own expenses. Perhaps there could be some incentive for the initial round of samples, so participation does not become limited by the inability to get started.

Figure a way to make use of all the tools that are available today, enhance them.

Farmers and land managers that are serious about committing their land toward an investment in service to ecosystems should be guaranteed a universal base income that meets a livable wage.

I said yes to all above because it would be great, but I have serious concerns of where all this money is going to come from. I don't believe there is the political or public will to support this to the extent necessary to fund it effectively.

Shift subsidies away from "failing" enterprises to encourage more rapid change in management practices.

Would be interesting to get VEDA/VACC involved with a lending option to assist farmers in making changes as long as the TSP and farmer can demonstrate it's for the better of the farm and environment.

How do you reward farmers who have been doing soil health practices all along, resulting in healthy soils with high organic matter percentages? Farmers who have led the way by being proactive in all segments of their agricultural endeavors, whether in soil health or animal health management.

Soil Health Management Systems would allow for the land manager to apply for assistance on a variety of practices under a single contract. This would increase enrollment and voluntary compliance with Required Agricultural Practices (existing and yet to come). Incentives are a favorable approach over regulations. Successful pilot projects and farmer-to-farmer training are proven methods for accelerating the adoption of healthy soils practices among the legacy farming community. Qualifying farmers should be enlisted as TSP staffers.

Each land manager would have a “team” of experts to help implement and troubleshoot. This team could coordinate with the Farm Viability Program to strive for successful outcomes at every level. Site characteristics and social context will be taken into account to ensure an equitable and just transition toward organic regenerative management. The aim is to ensure that land managers (and their employees) who adopt healthy soil practices are guaranteed a living wage.

Currently Addison Chittenden Counties are loosing two vital Extension personel

I think that more technical assistance on farms is helpful in general, and in relationship to this program it would be important for TSPs to be informed about it in order to be able to support folks in applying / participating. Depending on how the program looks, these questions may have different responses from me. If this program is based around a farm joining a program in which it develops a personalized plan for ecological improvement and that is guided by a relationship with a TSP over a few years of contract - then yes, there may be the need for increased technical assistance. If folks enrolled in a program fall between the cracks of other federally or State available funding, then there may also be the need for increased financial assistance. I would also consider the work done for the VT Strategic Ag Plan related to TSP needs, and to folks who currently are TSPs and who administer grants and funds for assistance. These folks have a lived understanding of current capacity and program dynamics.

I think this would go along well with a state bank system. A great thing for the state to invest in.

Verbatim responses to the question on biodiversity: *Please describe any further thoughts you may have on including a certain type(s) of biodiversity into the PES program. If you selected more than one option above, please describe the order of importance. Also, please consider your thoughts on how to quantify and the cost-benefit ratio of measuring the type(s) of biodiversity that you selected above.*

I think Soil macroinvertebrates is the most important as it usually is indicative of of teh presence of other metrics

Soil microbial #1 and Plant diversity #2

I understand it may not be practical initially to include biodiversity metrics across all the levels listed above. However, I feel strongly that in order to create a program that truly steers us in the direction of ecological health, biodiversity needs to be a focus. Focusing too narrowly on soil health measured in a given field will not necessarily lead to resilient farming systems or ecosystems.

All types included, but ranked as listed

It's not up to us to decide what species are more important than others. All species have intrinsic value in a system, whether or not they are being counted or valued or protected by humans.

Plant diversity and wildlife habitat both have many benefits and there are accessible tools to measure them (also could be directly observable). Regarding soil biodiversity: I am not a soil scientist, but as I understand it soil biodiversity is ephemeral and fairly inconsistent even within a single location, which I think would make it difficult to take accurate measurements.

I think the big picture is incredibly important--so prioritizing habitat and less disturbed areas like wetlands, forests, etc. Field edges are also important, providing habitat for birds, pollinators, beneficials, etc. I think the more minute measurables are more costly--very important but I feel like it's all connected, and addressing the whole farm system will support the less visible soil indicators.

Very difficult to choose, generally soil first, plant second and wildlife next. In the belief that plant diversity will help with wildlife diversity.

The Payment for Ecosystem Service and Soil Health Working Group is charged to build a PES program to support and enhance soil health on farms. Where a metric of soil health can include representative measurement of the health of the soil, soil microbial diversity and the presence of macroinvertebrates can help support the quantification of this soil health goal.

The IPCC has stated that loss of biodiversity is an equal or greater existential threat as climate change. Ag monitoring should start with soil but embrace whole landscape function.

I think habitat is the outcome that best matches the group's interest

Tree and Shrub plantings upstream, along field edges. Reintroducing native species that had been eroded from the landscape, that layer between economic benefit of land use lies between field and forest on the edge and maybe even in between. It does benefit, by establishing root systems, different for the large trees and short grasses, that suck up the water in other layers and pores of the soil and helping to stabilize the same. To secure the soil from increasingly heavy rainfalls that already show signs of erosion in the mountains, beginning to mark future brooks that bound their streams to the surface waters of the state. In the meantime, investing in the diversity of shrubs, including fruit and nut bearing trees promises an increase in local harvests of nourishing foods for the entire food chain.

Verbatim responses to the question on conservation effort and payment rate: *Please add any further thoughts you may have on the conservation effort required or the payment level that you would like to see in this program.*

I really need more information to answer the question about payment above. It would be helpful to see some data on how much it costs farmers on average to implement these practices, and to have more focused discussion on the question of valuation so we understand all the factors that go into developing payment rates.

In a pasture system, it's not about exactly how many days on pasture. They need to show they are using a holistic management approach to decision making, having completed a course and participating in an ongoing community of practice or "support group," and have a grazing plan that includes monitoring and adaptation based on how fast plants are regrowing, how much of plant animals are taking in how long. etc.

These questions are a little too limited and leading.

Last question is very complex. Funding could be coming from saved state and local costs on water cleanup, culvert and road rebuilds, private costs of air conditioning, public health/immunity, etc. etc. as well as external funding from carbon offsets etc.

I'd really like to include the whole farm ecosystem into this program. Also many of the questions vary depending on farm type--as should payment structure probably. Most diversified vegetable farms are >50 acres, but should still be incentivized to participate in this program, and have a lot of improvements needed to support Ecosystem services. Very different from field crops or hay fields interms of practice adjustments and payment incentives.

I think a crop rotating would work well, I also think grain crops that leave a lot of biomass would do well. Since we are measuring the soil, it should not matter what practices we think are important. The pay rate will never be perfect, but it does need to compensate for the additional time required to participate and act as a worthwhile reward for the achievement, not necessarily cover every single practice to produce the results. If the administrative part is simple, I can see the state getting more participation at a lower rate.

Some of these questions are hard to be definative about because so much depends on the farm circumstances and the level of management.

If the goal of the program is to compensate for performance outcomes, dictating the number of practices that need to be implemented seems counterintuitive for quantifying and compensating for performance. As it relates to a payment per acre, farmers are delivering uncompensated ES benefits that likely far exceed $200 per unit; and when compared to the value of the land and increasing development pressure, providing an equitable payment could likely exceed $200/acre/year.

Depending on where is the source of funding and for how long will it be available, can we make some of the payments as cost sharing instead of full payments covering the costs of practice adoptions? I guess I am coming from a standpoint where we may not have all the funding needed, and I think it is necessary to enroll as many farmers as possible rather that just a few fully funded. Thanks!

My answers were based on assuming this survey is clarifying base level requirements for enrollment---with the hope for deeper engagement with whole farm planning----and payment based on adoption of a Soil Health Management System.

This survey is based on a problematic assumption that practices lead to outcomes, when we see that empirical research indicates this is not always the case. It it not just about practices.

Current use pays more than $300 per acre simply for the agricultural use - PES has to be the premium tier of payments per acre in comparison.

Verbatim responses to the question on monitoring and verification: *If you have any other input related to monitoring and verification, please state it below.*

In the early stages in program it probably would be good to offer some TA and verify field management strategies.

Too much third party would be very expensive. However there needs to be some sort of verification to ensure the integrity of the program

The time it takes farmers and land managers to perform tests is extractive. If a farmer wants to do their own testing they should be paid to do so.

Essential if there is any hope for public/political support

I think it should definitely be done by a third party to ensure the program's credibility. But looking back to my prior comment about making sure funding is channeled to those people/organizations that are the focus of the program's objective, we should select that third party carefully and prioritize hiring other farmers, or VT-based TSP, etc., to do the sampling.

There should at least be some kind of third party verification system. Its important to avoid history repeating itself.

Third party soil sampling will guarantee honest results and can and probably should be cost shared. It will go into a state/ national database and is very valuable information. Most farmers don’t even have time to take the tests accurately.

Regards soil sampling, it is important for equitable and realistic results, that the type of testing be universal across the board, using the same class of test and methodology for measurement on every farm.

How it is appropriately monitored and verified depends on the program - how its structured around incentives / payments / etc. for practices and / or outcomes in particular. Sure, there is some incentive for farmers to selectively choose particular soils for sampling - and potentially TA providers - but I would imagine that kind of behavior to be very minimal. Some degree of monitoring and verification would go a ways towards ensuring honesty and transparency (and accuracy and understanding of the program and testing / monitoring needed from the farmer). I think that these requirements for monitoring could potentially be tiered based on scale of operation, and other factors. Perhaps there could be some sort of peer monitoring? Somethings are also already tracked and monitored in NMPs and perhaps that overlap could have some benefits for a new program. If the program were centered on a longer term relationship with a

TA provider and program through a multi-year contract, with a baseline payment and tiers on top (as CSP plus for example suggest), then monitoring would be ongoing and accountability very present.

Developing an estimated budget for the desired level of monitoring will be important in weighing the cost-benefit of payment for performance vs. practice.

I can see reasons for farmer testing (they learn more) but also for having a verifier come on occassion. If it's based on outcomes, and not a practice based system then verification of practices not needed.

Respondent Information

Verbatim response to the question: *Please feel free to provide any additional input or suggestions that you may have related to the design of this soil health PES program*.

Thanks for all your great work on this.

Thanks for your Efforts, this is starting to take shape, after months (years) of slowness. However the thought process was needed to get to this point. In the end it looks like simplicity may take the place of lots of complex discussions.

It needs to be clear and understandable not only to farmers, but also to the public (especially critics). Honesty and integrity are at the top of the list to show the public that the program either is or is not doing as designed.

Just reiterating my serious concerns with the cost of this program. That should be discussed.

I believe it is imperative to remain cognizant of the larger context in which this design work occurs. Mainstream climate scientists are shouting from the rooftops that we have maybe a 3-5 year window in which to mitigate the worst effects of irreversible abrupt climate change. To meet our binding greenhouse gas emission reduction targets as established under the passage of the VT Global Warming Solutions Act, to clean up our rivers and lakes, and renew our agricultural economy, we need to elevate healthy soil as an essential ingredient to solve the climate and ecological crisis. Simply reducing GHG emissions won’t be enough to halt climate change. We need to maximize the sequestration capacity of our farms and forests. More importantly, we need to focus on habitat restoration, maximizing landscape function, and restoring biodiversity.

Land managers need to be trained and supported to do this work. We must uncouple organic-regenerative farming from the capitalist system, or at least provide sufficient safety nets to guarantee a living wage for all farmers and farm workers engaged in organic regenerative land management.

Abrupt climate change is the symptom of the fundamental rupture from nature of settlement and colonialist culture. We can't expect farmers to focus on ecological services while they have to compete to survive in the industrial global food market. We need many more young people to work in regenerative organic land management as farmers and foresters. We must provide training and a viable career path for this fundamentally vital work of healing land and feeding local communities.

I feel strongly that our PES program should include biodiversity as a core ecosystem service for which farmers can be compensated. Without including biodiversity as central to this program design (both below and above ground), I'm very concerned that we will create a program that sets us further down a path of mono-cropping, consolidation, damage from chemical inputs, and ultimately a brittle system of agriculture that is not resilient to climate or economic instability.