Issue Paper
September 2019

Gund Institute for Environment www.uvm.edu/gund

Payment for Ecosystem Services for Vermont

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Citation
Hammond Wagner, C., Gourevitch, J., Horner, K., et al. 2019. "Payment for Ecosystem Services for Vermont." Issue Paper 19-01. Burlington, VT: Gund Institute for Environment.

Acknowledgments
A Spring 2019 class led to the development of this paper, with numerous guests sharing their perspectives on water quality, agriculture and PES in Vermont. Their perspectives informed our learning on these issues and the development of this paper. Guests were not asked to endorse the paper or recommendations herein, and they did not see a final draft of this paper. In particular, we thank Gil Livingston, Deb Markowitz, Marie Audet, Chuck Ross, Neil Kamman, Marli Rupe, Mark Magnan, Joshua Faulkner, Roger Albee and Jim Salzman for their insights. We also thank Donna Rizzo, Christopher Koliba and Joshua Faulkner for their review of an earlier draft. The responsibility for the content of the paper lies solely with the authors.

EXECUTIVE SUMMARY

We are confident that a payment for ecosystem services (PES) for Vermont, if designed in a careful, inclusive and pragmatic way, can both contribute to improvements in water quality in the state and support the economic viability of Vermont farms. PES has emerged as a potential solution to the dual challenges of water quality and a struggling agricultural economy currently impacting the state of Vermont. This white paper summarizes the major insights and recommendations of a Spring 2019 Gund Institute graduate seminar on designing a PES for Vermont. Our recommendations stem from the body of literature on PES program design and our assessment of the current tools and resources available for water quality and agriculture efforts in the state. We align our proposed PES with Vermont's goals for improved water quality and a flourishing agricultural economy supported by policy makers, environmentalists and agricultural stakeholders alike.

We suggest that an overarching goal for a PES in Vermont is a program that will incentivize long term water quality improvements while supporting Vermont's agricultural community. We identify five program objectives that we use to guide our proposed program design for a PES for Vermont:

1. Support economic viability for farmers with a PES program that is voluntary, equitable and provides flexibility for farmers to adopt strategies that fit their farm systems.
2. Incentivize innovative and sustainable agricultural land management that provides multiple ecosystem services (phosphorus and carbon)
3. Make measurable contributions on agricultural lands to meeting state environmental goals
4. Enhance community support and public trust for agriculture
5. Compensate farmers for measurable performance gains, rather than changes in practice

Within this white paper, we describe in detail a potential PES program for phosphorus load reduction, including an approach to measuring phosphorus load reduction from participating farms and a payment structure to compensate farmers for their load reduction. We also introduce the option of including multiple ecosystem services in the PES, specifically phosphorus load reduction and carbon sequestration, in order to demonstrate how the PES could accommodate additional services, though we largely focus on the program design for phosphorus.

To measure ecosystem service provisioning by participating farms, we propose to measure phosphorus load and carbon emissions at the level of the farm system, using two metrics for each service. The use of two metrics allows the program to capture both the short-term and long-term impacts to service provisioning. Specifically:

- For phosphorus load reduction, we recommend summing a participating farm's farmgate phosphorus balance and aggregate field P loss risk relative to a baseline. Considerations for setting a baseline are discussed within the report.
- For carbon sequestration, we recommend measuring direct carbon emissions associated with farm activities and stocks of soil organic carbon in fields.

We propose to pay farmers for their ecosystem service reduction (phosphorus lb/yr or carbon dioxide equivalent/yr) relative to a baseline to incentivize management changes that provide these services. For phosphorus payments, the literature suggests that an appropriate range of payments per pound phosphorus is $10 to $100 per pound. We propose that payments be differentiated to farms based on farm size, to account for differences in abatement costs, and by TMDL priority watershed, to support achieving the TMDL reduction goals for phosphorus. This report presents costs estimates for different load reductions and payment prices for phosphorus. **If a PES were designed to capture 10% of the TMDL phosphorus load reduction required by the five Vermont watersheds facing the largest reduction from the agricultural sector at a price of $25 per pound of P, we estimate that the payments would cost $650,000 per year.** We are careful to note that these estimates do not account for administrative costs of the PES.

We suggest that a publicly-funded PES would best suit the Vermont context, as opposed to a model in which ecosystem services beneficiaries (e.g. citizens who benefit from improved water quality) directly pay service providers. A public buyer structure better accounts for the diverse watershed dynamics throughout the Lake Champlain Basin and existing regulatory requirements. In this model, the program would administer funds on behalf of the public through an intermediary organization, which preferably is an existing, well-respected and trusted organization. It is likely that state funds for achieving the TMDL could be used to fund the phosphorus load reduction payments. We are unable to identify a viable funding source for carbon sequestration payment at this time. If a funding source for both phosphorus and carbon payments were identified, we suggest layering payments such that a farmer would receive a separate payment for each service.

With our proposed program objectives, measurement models and payment structure, it is important to consider implications for program additionality (e.g. the additional phosphorus load reduction attributable to the program), permanence of management changes and equity impacts:
- We propose the use of differentiated payments and layering phosphorus and carbon benefits to promote broad program participation, equalize the farmer livelihood impacts of participation and target areas of greatest concern from a water quality standpoint.
- We suggest that prior to implementation, careful consideration is given to selection of a measurement baseline for payments as this has important equity implications in terms of which farmers benefit most from the program.

- Our program proposal encourages farmers to innovate with practices, systems and/or technologies that most efficiently enable them to measurably reduce phosphorus loading to surface water. This has been found to increase the likelihood of permanence in PES programs.

We end our proposal with next steps to move a PES for Vermont from concept to reality. **We recommend that program design and implementation be a stakeholder driven process in which many voices are invited to participate**. Prior to implementation and as a part of this stakeholder process, we recommend that important knowledge gaps are addressed, specifically relating to ecosystem services metrics, sensitivity of the metrics to management changes and the appropriate price to pay farmers for performance. Finally, we suggest that the PES program should build in a continuous process for monitoring, evaluation and program refinement.
We see a PES for Vermont as an exciting possibility to recognize and reward farmers as stewards of ecosystems and providers of important benefits to the public, while helping Vermont to achieve its environmental goals.

1. Introduction

Payment for Ecosystem Services (PES) has emerged as a potential solution to the dual challenges of water quality and a struggling agricultural economy currently impacting the state of Vermont.[1] This white paper summarizes the major insights and recommendations of a Spring 2019 Gund Institute graduate seminar on designing a PES for Vermont. Our recommendations stem from the body of literature on PES program design and our assessment of the current tools and resources available for water quality and agriculture in the state. We align our proposed PES with Vermont's goals for improved water quality and a flourishing agricultural economy supported by policy makers, environmentalists and agricultural stakeholders alike.

Vermont and the Environmental Protection Agency (EPA) have clearly articulated goals for water quality improvement in the Lake Champlain Basin. Excessive phosphorus (P) runoff into surface waters has reached a tipping point in the Basin with frequent toxic algal blooms, eutrophication and social and economic consequences for the Vermont public.[2] Despite decades of effort to improve water quality, indicators continue to show little progress.[3] As a result, the EPA recently forced Vermont to increase efforts to clean up the lake.[4] Vermont is now charged with achieving a reduction in P flows entering the lake in the form of a revised Total Maximum Daily Load (TMDL). The TMDL specifies the maximum quantity of P that can enter the lake while still achieving Vermont's water quality standards.[5] Approximately 41% of problematic P pollution entering Lake Champlain is attributed to agriculture, and farms are expected to make significant changes to reduce P loading to the lake.[6] In fact, agriculture is required to reduce P pollution by 56% under the TMDL, which is more than its share of the problematic P entering the lake.[7]

Simultaneously, the agricultural economy in Vermont is struggling. Vermont dairy farmers are facing the fifth year of low milk prices and, as a result, 10% of the state's

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[1] Brian Kemp, Larry Gervais, and Paul Doton, "A Proposal to Explore How to Value Agriculture Ecosystem Services in Vermont," 2019, https://legislature.vermont.gov/Documents/2020/WorkGroups/House Agriculture/Clean Water Initiative/W~Jeff Carter~A proposal to explore how to value agriculture ecosystem services in Vermont~2-14-2019.pdf; Vermont Dairy and Water Collaborative, "A Call to Action," 2019, https://www.vtfarmtoplate.com/assets/resource/files/VDWC Final Report Compilation.pdf.

[2] Lake Champlain Basin Program, "2018 State of the Lake and Ecosystem Indicators Report" (Grand Isle, VT, 2018).

[3] Lake Champlain Basin Program, 2018.

[4] Keri Dolan, "The Importance of Inter-Agency Collaboration and Public Engagement in the Development of the Implementation Plan for the Nonpoint Source-Focused Vermont Lake Champlain Phosphorus TMDL," *Vermont Journal of Environmental Law* 17, no. 4 (2016): 663–83, https://www.jstor.org/stable/vermjenvilaw.17.4.663.

[5] Dolan.

[6] EPA, "Phosphorus TMDLs for Vermont Segments of Lake Champlain, June 17, 2016," 2016.

[7] EPA, 2016.

dairy farms went out of business in 2018.[8] Dairy farms make up the majority of the agricultural land use in the state, primarily in corn, hay or pasture fields.[9] The future of those working landscapes and the viability of Vermont agriculture in general are precarious.

We suggest that an overarching goal for a PES in Vermont is a program that will incentivize long term water quality improvements while supporting Vermont's agricultural community. In this white paper, we present a plan for a program that pays farmers to reduce P loading through performance improvements above and beyond existing regulatory requirements. We also discuss options for including other ecosystems services such as carbon (C) sequestration. In the sections that follow, we propose a system to measure P load reduction performance with existing data and tools already supported by agricultural service providers. We further propose a payment structure for the program and identify potential sources of funding. We then summarize several important considerations that can affect the success of the program, such as balancing equity and program impact. Finally, we suggest next steps needed to bring the project from concept to reality, including deliberating with stakeholders, addressing knowledge gaps and initiating a pilot study. First, we begin in the next section with a brief primer on PES and attributes of PES programs.

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[8] U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS), "2017 Census of Agriculture - Volume 1, Chapter 1: State Level Data," 2017, https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/Vermont/ ; "Vermont Agency of Agriculture, Food and Markets Report and Recommendations of the Vermont

[9] "Vermont Agency of Agriculture, Food and Markets Report and Recommendations of the Vermont Milk Commission to the Vermont Legislature"; U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS), "2017 Census of Agriculture - Volume 1, Chapter 1: State Level Data."

2. PAYMENTS FOR ECOSYSTEM SERVICES CONCEPT

A PES is an incentive program or partnership built on the concept of ecosystem services.[10] Ecosystem services are benefits provided by ecosystems to people. This can include the provisioning of goods, such as food, water and lumber, the regulation of clean air, stable climate or flood mitigation, supporting services, such as nutrient retention or soil formation, and cultural services, such as recreational, spiritual or mental health benefits.[11] At its core, a PES is a program or exchange in which a party pays another party to provide ecosystem services that benefit them. In other words, beneficiaries of a PES pay land managers to "supply" a certain level of ecosystem services. Ecosystem services are provided by natural systems whether or not anyone is paid to provide them. However, PES schemes place value on ecosystem services, here in the form of a payment to land managers, to encourage ecosystem service provisioning and counteract market pressures that may further degrade them.

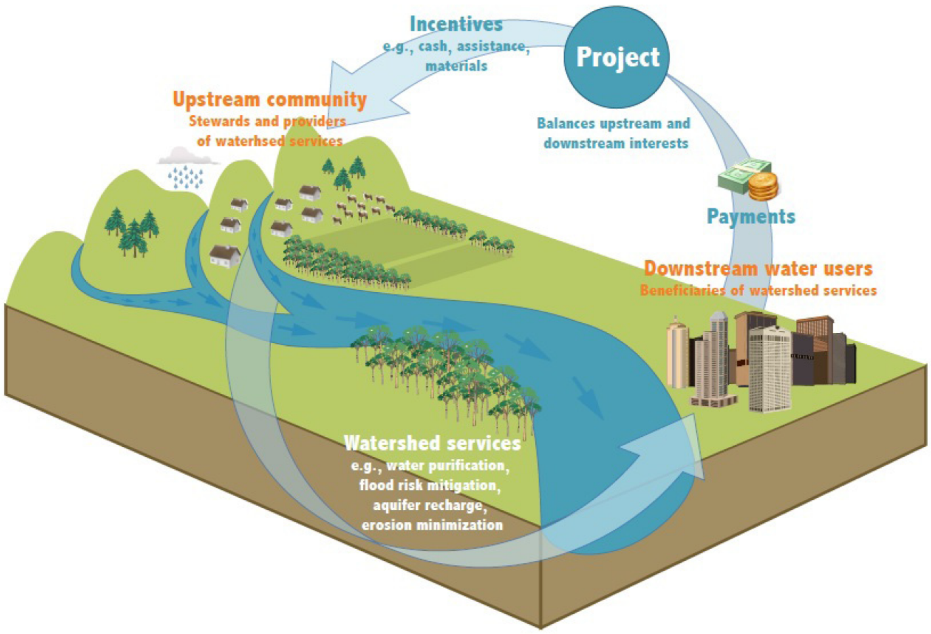

Figure 1. Representation of a PES scheme in which downstream water users pay upstream land owners to provide watershed services, used with permission by Smith et al. (2013).[12]

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[10] Wunder, S., 2005. Payments for Environmental Services: Some Nuts and Bolts. Occasional Paper No. 42. Center for International Forestry Research, Nairobi, Kenya.

[11] Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington, DC. http://www.millenniumassessment.org/documents/document.356.aspx.pdf

[12] S. Smith et al., "Payments for Ecosystem Services: A Best Practice Guide. Draft Guide for Stakeholder Comment," 2013, https://www.cbd.int/financial/pes/unitedkingdom-bestpractice.pdf.

PES schemes have several important characteristics that differentiate them from other incentive-based programs that aim to improve environmental performance.[13] We recommend that any scheme implemented in Vermont be based on the following five principles that typically characterize a PES[14]:

1. **Voluntary** – PES schemes are voluntary and have no legal requirement for a PES seller to participate. Land managers can decide whether the additional benefit provided by the PES program makes participation worth it. Parties may end their participation in the program based on the terms of the contract or the requirements laid out for program participation.
2. **Beneficiary Pays** – Those that receive the benefits from the ecosystem service pay for the provisioning of the service, which stands in contrast to a "polluter pays" approach. An important distinction between these two approaches is that in the later, land managers are framed as polluters, whereas with a PES, land managers are framed as stewards.
3. **Direct Payment** – Within a PES, payments go from beneficiaries to providers; sometimes directly, though frequently through an intermediary that assists beneficiaries and providers in managing the PES.
4. **Additionality** – This concept refers to the provisioning of ecosystem services that would not have occurred without a PES incentive.[15] Typically, a PES only pays for the additional provisioning of ecosystem services that wouldn't have occurred otherwise so that the program can be credited for the additional provisioning.
5. **Conditionality** – Payment in a PES scheme depends on the condition that ecosystem services are being delivered as agreed upon.

[13] PES are often described as a market-based instrument to incentivize ecosystem service provisioning through the use of payments. Other market-based instruments include environmental taxes, eco-labels, subsidies and cap-and-trade programs.

[14] These principles are based on those recommended for PES schemes found in Smith et al. 2013

[15] J Börner et al., "The Effectiveness of Payments for Environmental Services," *Elsevier*, accessed June 11, 2019, https://www.sciencedirect.com/science/article/pii/S0305750X17300827.

3. Designing a PES for Vermont

In the sections that follow, we introduce our design considerations and recommendations for a PES for Vermont. We describe a PES that pays farmers for the services of P retention and C sequestration. The PES elements designed herein are targeted to fit the unique context of Vermont's agriculture and water quality needs and to result in lasting water quality improvements, encourage sustainable farming practices and support Vermont's agricultural landscape. True to the definition of PES, we describe a program that is voluntary, follows a beneficiary pays principle, offers direct payments to farmers for ecosystem services provided, takes into consideration additionally and ensures conditionality.

We begin in this section by outlining specific program objectives to meet the goal of improving water quality while supporting farmers. We define these desired program objectives for a Vermont PES in Box 1 that led us to define a PES for P retention and C sequestration. Below, we elaborate on the definition and rationale for each of these five desired objectives.

Box 1. Five objectives for a Vermont PES

1. Support economic viability for farmers with a PES program that is voluntary, flexible and equitable
2. Incentivize innovative and sustainable agricultural land management that provides multiple ecosystem services (P and C)
3. Make measurable contributions on agricultural lands to meeting state environmental goals
4. Enhance community support and public trust for agriculture
5. Compensate farmers for measurable performance gains, rather than changes in practice

3.1. Support economic viability for farmers with a PES program that is voluntary, flexible and equitable

While rural economic development is not always an explicit goal for PES programs, this has been a major part of the rationale in the PES discussion in Vermont.[16] The PES program we describe herein is not designed to rescue Vermont farms from market pressures, but this program could relieve some economic pressures by creating a

[16] Vermont Dairy and Water Collaborative, "A Call to Action"; Kemp, Gervais, and Doton, "A Proposal to Explore How to Value Agriculture Ecosystem Services in Vermont."

revenue stream that is not tied to the price of agricultural products. To support famers and be successful in the long-term, a PES in Vermont requires farmer buy-in. As such, we suggest the PES should be voluntary and flexible to respond to farmer input. This program should not seek to replace or mimic regulation, but complement it by giving farmers the opportunity to be rewarded for their measured contributions to environmental goals. This type of PES program design would support farmers in innovating towards increased agricultural sustainability and diversifying their operations as they see fit. We also posit that a program that takes into consideration equity concerns is more likely to gain broad support from the agricultural community, and thus we make this an explicit objective for our program design.

3.2. Incentivize innovative and sustainable agricultural land management that provides multiple ecosystem services

Vermont agricultural lands provide a number of ecosystem services to the public, including food production, C sequestration, nutrient retention, flood regulation, cultural services and biodiversity support.[17] The ecosystem services of nutrient retention (i.e. P load reduction) and C sequestration are well-poised to be integrated into a performance-based Vermont PES design and to contribute to Vermont's environmental goals, as shown in Figure 2. These two services are complementary in that many soil management practices that increase C sequestration also increase the efficiency of nutrient retention to benefit water quality.[18] Additionally, established PES programs exist elsewhere around these ecosystem services, which we can reference for program design.[19] These two ecosystem services can also be measured or modeled, which makes estimating the value and the contribution from each farm possible. Perhaps most importantly, farm management decisions in Vermont have the potential to enhance nutrient retention and C sequestration, which make them excellent candidates for PES program.[20]

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[17] Power, A. G. "Ecosystem services and agriculture: tradeoffs and synergies." *Philosophical transactions of the royal society B: biological sciences* 365, no. 1554 (2010): 2959-2971.

[18] Graham K. Macdonald et al., "Guiding Phosphorus Stewardship for Multiple Ecosystem Services," *Ecosystem Health and Sustainability* 2, no. 12 (December 19, 2016): e01251, https://doi.org/10.1002/ehs2.1251.

[19] Two examples are California's Healthy Soils Program, which pays farmers to sequester carbon on their agricultural fields and New Zealand's Lake Taupo Protection Trust, which purchased nitrogen from farms to reduce nitrogen loading to Lake Taupo. For a description of the Healthy Soils Program see: California Department of Food and Agriculture (CDFA). (2018). Request for Grant Applications. 2018 Healthy Soils Program Incentives Program. California Department of Food and Agriculture (CDFA). 19 pages. For a description of the Lake Taupo program see: S Yerex, "Protecting Lake Taupo: The Strategy and the Lessons," 2009, http://dspace.lincoln.ac.nz/handle/10182/5965.

[20] S. T. Lovell et al., "Integrating Agroecology and Landscape Multifunctionality in Vermont: An Evolving Framework to Evaluate the Design of Agroecosystems," *Agricultural Systems* 103, no. 5 (2010): 327–41.

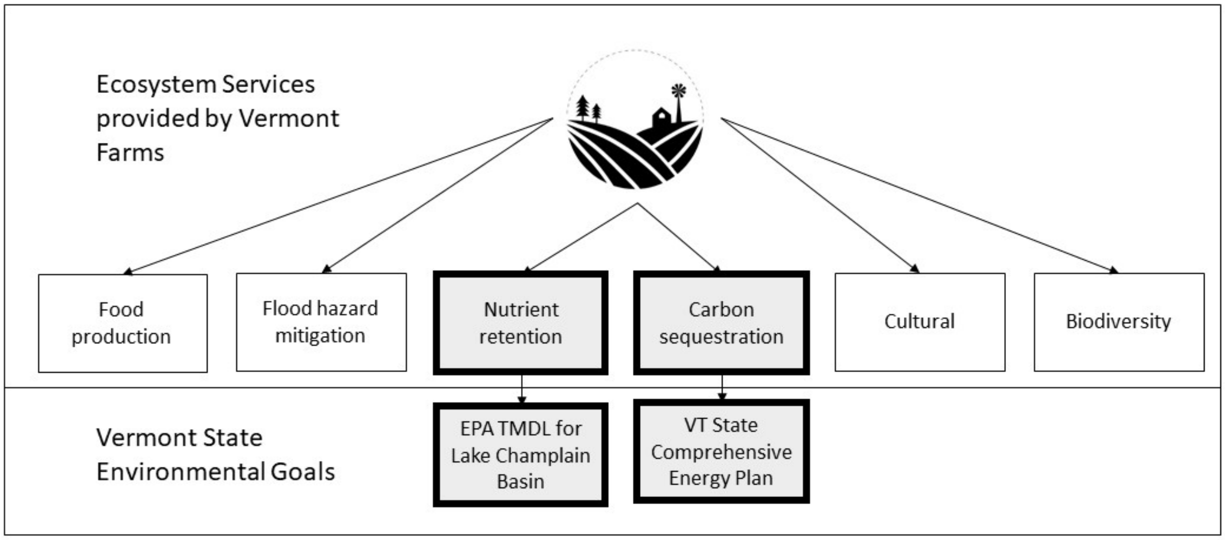

Figure 2. Vermont farms provide ecosystem services to the public and are important components of achieving Vermont State's environmental goals

3.3. Make measurable contributions on agricultural lands to meeting state environmental goals

The state of Vermont has outlined both C and P related environmental goals with contributions expected from agricultural landscapes. We suggest that a Vermont PES can contribute to meeting these goals. As mentioned in the introduction, the state's mandated TMDL plan sets targeted reductions in non-point source P pollution from agriculture into Lake Champlain.[21] The Required Agricultural Practices (RAPs) were introduced in 2016 by the Vermont Agency of Agriculture, Food and Markets (VAAFM) as a set of rules and required practices for all Vermont farms to reduce P runoff from farms.[22] However, it is generally acknowledged that the RAPs will not be sufficient to achieve the required TMDL reductions in all of the Lake Champlain Basins watersheds.[23] This presents an opportunity for a Vermont PES program to incentivize reductions beyond those required by the RAPs and to contribute to meeting the State's TMDL.

Concurrently, the state's Comprehensive Energy Plan committed Vermont to reducing greenhouse gas emissions.[24] The plan has identified the potential for agricultural best management practices to contribute 11% of the state's reduction goal, a reduction of

[21] EPA, "Phosphorus TMDLs for Vermont Segments of Lake Champlain, June 17, 2016."

[22] VAAFM, "Vermont Required Agricultural Practices Rule for the Agricultural Nonpoint Source Pollution Control Program," 2018, https://agriculture.vermont.gov/sites/agriculture/files/documents/RAPFINALRULE12-21-2018_WEB.pdf.

[23] Hirschfeld, P. "After 3 years, funding plan to improve Vermont's Water Quality remains elusive." *Vermont Public Radio News* 2018, https://www.vpr.org/post/after-3-years-funding-plan-improve-vermonts-water-quality-remains-elusive#stream/0.

[24] State of Vermont, "Executive Department Executive Order No.12-17." (Montpelier, VT, 2017), https://governor.vermont.gov/sites/scott/files/documents/EO 12-17 - Climate Action Commission.pdf.

22,000 metric tons of CO_2.[25] A Vermont PES could be the vehicle through which Vermont farmers are incentivized to adopt BMPs to reduce greenhouse gas emissions to meet Vermont's Comprehensive Energy Plan goals.

3.4. Enhance community support and public trust for the agricultural community

A PES would offer farmers an incentive to elevate land stewardship practices above and beyond regulatory requirements. As a voluntary program, the PES would offer an opportunity to reframe the historically heated conversation about water quality in the state through celebrating the farming community's expertise, vision, motivation and compassion to improve environmental quality for future generations. As such, a PES for Vermont could foster respect and trust for the farming community from the non-farming public.

3.5. Compensate farmers for measurable performance gains, rather than changes in practice

We suggest that a PES for Vermont should be based on payments for measured improvements in environmental performance. This is in contrast to the dominant model for incentivizing ecosystem services from agricultural landscapes, which pays farmers for adopting specific conservation practices. The *practice-based* model fails to account for how site and soil variability influence the effectiveness of a practice and limits the ability of farmers to innovate. Programs that incentive performance reward farmers based on quantifiable outcomes, but have historically been too expensive and burdensome to monitor and verify.[26] Advances in measurement and modeling tools have created an opportunity for *performance-based* payment programs. A Vermont PES program that is performance-based would quantify ecosystem service provisioning from farms and reward farmers for their measured contributions to public goods. Incentives based on impacts could both motivate innovation on farms towards increasing ecosystem services beyond regulatory requirements (such as the RAPs) and offer accounting of agricultural contributions to environmental goals for policy-makers. For further justification of our decision to support a performance-based program design, see Box 2.

A risk of a performance-based system is that farmers may make changes that cost them money but do not result in a measurable change in metrics monitored and thus there is no payment. Additionally, performance-based systems can feature higher program transaction costs because the monitoring and verification of performance is typically more costly. Despite these risks, Vermont is well positioned to implement a performance-based PES and, for the five reasons listed in Box 2, we propose that a performance-based approach is the preferred approach for Vermont.

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[25] See Walke, P. et al., "Final Vermont Climate Action Commission Report to the Governor on Executive Order No.12-17" (Montpelier, VT, 2018). For context, Walke et al. states that it is estimated that broad best management practice adoption across all agricultural lands in the state (e.g. cover cropping and reduced tillage) could contribute 50,000 metric tons of carbon dioxide reduction.

[26] Kristin Fisher et al., "Pay-for-Performance Conservation: A How-to Guide," 2017, https://www.winrock.org/wp-content/uploads/2016/02/PfP-How-To-Guide-Final.pdf.

Box 2. Justifications for implementing a performance-based PES as opposed to a practice-based PES

Why pay for performance? Why not practice?
1. Many practices have limited and varied effectiveness for P load reduction (especially over longer time horizons and different farm geography, soil conditions, etc.)[27] 2. The RAPs and other practice-based systems already exist. PES can capture efforts that may fall outside of the realm of these programs.[28] 3. Performance enables a focus on two linked components of the P problem (i.e., accumulation of legacy P and P runoff) – practices have typically been targeted largely on the latter, but both are important.[29] 4. Data needed to determine performance are readily available and straightforward protocols exist (see measurements section below).[30] 5. Performance provides room for farmer innovation, flexibility to tailor to the farm system.[31]

[27] Dodd, R. J., and A. N. Sharpley. "Conservation Practice Effectiveness and Adoption: Unintended Consequences and Implications for Sustainable Phosphorus Management." *Nutrient Cycling in Agroecosystems* 104, no. 3 (2016): 373–392.; Sprague, Lori A., and Jo Ann M. Gronberg. "Relating Management Practices and Nutrient Export in Agricultural Watersheds of the United States*."* *Journal of Environmental Quality* 41, no. 6 (2012): 1939–1950.; Hoffmann, Carl Christian, Charlotte Kjaergaard, Jaana Uusi-Kämppä, Hans Christian Bruun Hansen, and Brian Kronvang. "Phosphorus Retention in Riparian Buffers: Review of Their Efficiency." *Journal of Environmental Quality* 38, no. 5 (September 1, 2009): 1942–55. https://doi.org/10.2134/jeq2008.0087.; Jarvie, Helen P., Laura T. Johnson, Andrew N. Sharpley, Douglas R. Smith, David B. Baker, Tom W. Bruulsema, and Remegio Confesor. "Increased Soluble Phosphorus Loads to Lake Erie: Unintended Consequences of Conservation Practices?" *Journal of Environmental Quality* 46, no. 1 (2017): 123–132.; Sharpley, Andrew N., Peter JA Kleinman, Philip Jordan, Lars Bergström, and Arthur L. Allen. "Evaluating the Success of Phosphorus Management from Field to Watershed." *Journal of Environmental Quality* 38, no. 5 (2009): 1981–1988.

[28] VAAFM, 2018.

[29] Wironen, Michael B., Elena M. Bennett, and Jon D. Erickson. "Phosphorus Flows and Legacy Accumulation in an Animal-Dominated Agricultural Region from 1925 to 2012." *Global Environmental Change* 50 (2018): 88–99.; Kusmer, A. S., J.-O. Goyette, G. K. MacDonald, E. M. Bennett, R. Maranger, and P. J. A. Withers. "Watershed Buffering of Legacy Phosphorus Pressure at a Regional Scale: A Comparison across Space and Time." *Ecosystems* 22, no. 1 (2019): 91–109.; Sharpley, Andrew, Helen P. Jarvie, Anthony Buda, Linda May, Bryan Spears, and Peter Kleinman. "Phosphorus Legacy: Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment." *Journal of Environmental Quality* 42, no. 5 (10/01 2013): 1308–26. https://doi.org/10.2134/jeq2013.03.0098.

[30] See description of measurement models, tools and resources in the "Measuring Performance" section.

[31] Fisher et al., 2017.

4. MEASURING PERFORMANCE

Performance systems must determine how best to measure ecosystem service benefits. For a Vermont PES, this translates to measuring P load and C emissions from participating Vermont farms. The PES would then pay farmers for their measured reductions in P load (i.e. P retention) and net C emissions. We propose that reductions in P loading to water bodies be monitored through changes to two metrics: *field P loss* (lbs P yr^{-1}), and *farm P balance* (lbs P yr^{-1}). Similarly, we propose that reductions in net C emissions be monitored through changes to two metrics: *farm C emissions from equipment and animals* (lbs CO_2eq yr^{-1}) and *soil organic C (SOC) accumulation* (lbs CO_2eq yr^{-1}). We've selected these measurements, which are described in greater detail below, because they use existing farm data, they are non-proprietary and they are supported by the University of Vermont Extension.[32]

Additionally, for measuring P and C in the program, we propose that the ecosystem boundaries include the entire farm. We define the farm ecosystem as infrastructure, animals and non-protected lands owned or leased by a farm that contribute to farm related expenses and income.[33] Taking measurements at the farm system boundary would allow the program to pay for any positive changes in the farm system, including both the adoption of technical innovation (e.g., no till) and decreased farming intensity (e.g., reduced animal numbers).

Given time and capacity constraints in the writing of this white paper, we focus greater detail in this section on the proposed metrics for measuring P load reduction from Vermont farms. We lay the groundwork for measuring and incorporating C, but this portion is less developed in this section and in the payment section to follow.

4.1. Phosphorus

We propose calculating P load reduction by summing a participating farm's farmgate P balance and aggregate field P loss risk (Equation 1 below). We combine these two metrics because they measure different aspects of farm's P dynamics that each contribute in important ways to P retention.

Equation 1: $P\ load\ metric\ [lbs\ P\ yr^{-1}] = farm\ P\ balance + \ field\ P\ loss$

[32] It is crucial that the measurement system for the PES be appropriate for the level of funding and resources available to support it. Building a comprehensive model for each service, that includes all possible factors that may contribute to it, is likely to be prohibitively expensive and overly complicated. Therefore, the metrics that we propose rely on available measurement models that closely approximate the desired services. This approach strikes a balance between the need for accuracy and verification and the costs of data collection and modeling.

[33] Should a field be placed into conservation easement we suggest that it should no longer be considered part of the farm ecosystem. Any ecosystem services being provisioned on a conservation easement owned by farm would not be paid for by the program because the farm will receive other financial benefits from that easement. Converting a field to conservation easement may, however, still result in ecosystem services payment. For example: If a farm reduced the size of its herd and retired several fields and as a result decreased the overall farm P balance and C emissions, then it would still garner payment.

The first metric, the farmgate P balance is an accounting of P flows entering and exiting the boundaries of the farm system. On average, conventional farms import more P than they export through the farmgate, which results in the accumulation of legacy P in the landscape and increased transport of P to waterways.[34]

The second metric, field P loss risk, considers source and transport factors that affect P loss from each individual field.[35] Historically conservation efforts have focused on field P loss and ignored the overarching issue of watershed scale imbalances in P import and export, which can be approximated with the farm P balance metric.[36] Therefore, through the use of these two metrics, the PES would mitigate future P load by incentivizing a reduction in P surplus, and mitigate present day loads by incentivizing a reduction in field P loss.

Farm P balance

To estimate Farm P balance, we recommend use of the Cornell whole farm nutrient mass balance tool for P, which calculates the difference between imports and exports of P through the farmgate (Equation 2).[37] Imports and exports in the mass balance represent flows of P in materials passing through a farmgate. A farm with P surplus value is accumulating nutrients on their property that can potentially be lost to surface waters over time, whereas a farm with a farmgate P deficit is mining nutrient stocks from the farm ecosystem. Recent research on New York dairies indicates that farm P balance decreased on average between 2005 and 2010, and that the Cornell nutrient mass balance was a promising adaptive management tool for farmers to evaluate nutrient and cost efficiency.[38]

Equation 2: $$Farm\ P\ balance\ [lbs\ P\ farm^{-1}\ yr^{-1}] = imports - exports$$

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[34] Cela, Sebastian, Quirine M. Ketterings, Karl Czymmek, Melanie Soberon, and Caroline Rasmussen. "Long-Term Trends of Nitrogen and Phosphorus Mass Balances on New York State Dairy Farms." *Journal of Dairy Science* 98, no. 10 (2015): 7052–7070.; Sharpley, Andrew, Doug Beegle, Carl Bolster, Laura Good, Brad Joern, Quirine Ketterings, John Lory, Rob Mikkelsen, Deanna Osmond, and Peter Vadas. "Phosphorus Indices: Why We Need to Take Stock of How We Are Doing." *Journal of Environmental Quality* 41, no. 6 (2012): 1711–1719.; Wironen et al., 2018.

[35] For reference, farm P surplus is on the order of -10 to 50 lb P $acre^{-1}$ yr^{-1} while field P loss is on the order of 0.1-1 lb P $acre^{-1}$ yr^{-1} *See* Cela et al., 2015, and Sharpley et al., 2012.

[36] R. J. Dodd and A. N. Sharpley, 2016.

[37] Soberon, M. A., Q. M. Ketterings, C. N. Rasmussen, and K. J. Czymmek. "Whole Farm Nutrient Balance Calculator for New York Dairy Farms." *Natural Sciences Education* 42, no. 1 (2013): 57–67.

[38] Soberon, M. A., S. Cela, Q. M. Ketterings, C.N. Rasmussen, and K. J. Czymmek. "Changes in Nutrient Mass Balances over Time and Related Drivers for 54 New York State Dairy Farms." *Journal of Dairy Science* 98, no. 8 (2015): 5313–5329.

Field P loss
Field P loss can be calculated using the Vermont P Index (VPI). The VPI estimates the risk of P loss from a field to the nearest waterway by considering source and transport factors, both of which can be affected by farm management changes. Specifically, the VPI uses soil test data, fertilizer/manure application rates and field characteristics to estimate the P transport risk associated with three pathways: *surface P particulate runoff* (i.e. the sum of eroded soil and particulate manure), *surface P dissolved runoff* (i.e. the sum of losses from soil, manure and fertilizer) and *subsurface P particulate and dissolved loss* (i.e. particulate and dissolved losses through tile drains).

To calculate VPI, P loss rates (lbs P per acre per year) are estimated for each pathway then multiplied by a scaling factor to develop an index between zero and 100 (Equation 3). To measure P loss from fields for the PES, we propose to simply remove the scaling factor from the VPI calculation (Equation 4). Finally, Field P loss for an entire farm can be calculated as the P loss rate times the area, summed for all fields on a farm (Equation 5).

Equation 3: $$VPI = \sum_{pathway=1}^{3} \left(loss\ rate_{pathway} * scaling\ factor_{pathway}\right)$$

Equation 4: $$P\ loss\ rate\ [lbs\ P\ acre^{-1}\ yr^{-1}] = \sum_{pathway=1}^{3} \left(loss\ rate_{pathway}\right)$$

Equation 5:
$$Field\ P\ loss\ [lbs\ P\ farm^{-1}\ yr^{-1}] = \sum_{field=1}^{number\ of\ fields} \left(P\ loss\ rate_{field} *\ Area_{field}\right)$$

In the future, other models of P loss, such as fate and transport models (e.g. FarmPREP[39]), or more complex site assessment tools, may prove to be more accurate and or cost effective than VPI. Should this be the case we suggest that the PES could substitute the VPI with a different index. However, current evidence suggests that numerical fate and transport models require extensive calibration and highly specialized expertise to operate correctly while offering similar accuracy as site assessment tools like VPI.[40] Furthermore, numerical modeling options to assess P loss limit the opportunities for entrepreneurs or farmers to easily assess P loss themselves. Therefore, it is our assessment that the VPI[41] provides the best balance between measurement accuracy and accessibility for farmers. To further improve the VPI, future updates could focus on field validation of VPI in a variety of soils, landscapes, farm types, etc.

[39] https://farm-prep.net/info/#text-1

[40] A Sharpley et al., "Evaluation of Phosphorus Site Assessment Tools: Lessons from the USA," *Dl.Sciencesocieties.Org*, accessed June 5, 2019,

[41] It is also worth noting that the VPI is revised periodically, the current version (VPI 6.1) was revised in February 2018. VPI could be updated in the future to allow more flexibility to farmer innovation this could be done by changing discrete inputs into continuous ones (e.g. changing cover from yes/no to biomass or stem density of cover crop).

4.2. Carbon

Similar to the P metrics, we propose to measure net CO_2-eq emissions reductions as changes to two metrics: GHG emissions associated with farm activities (e.g. grazing cattle, operating equipment), and field C sequestration (i.e. stocks of soil organic C in fields). Net emissions reduction can be measured as the difference between farm CO_2-eq emissions and field CO_2-eq sequestration (Equation 6). Measuring sequestration and emissions together can help incentivize net reductions in C emissions for the entire farm and avoid potential tradeoffs between sequestration and emissions.[42]

Equation 6:

$$Net\ C\ emissions\ [lbs\ CO_2 eq\ yr^{-1}] = farm\ C\ emissions - \ field\ C\ sequestration$$

Farm C emissions

Farm C emissions can be calculated as the sum of fossil fuel combustion emissions, including direct emissions on the farm (e.g., diesel and gas for equipment, emissions from structures where fossil fuels are used for heating, electricity, etc.) and indirect emissions (e.g., emissions occurring off farm associated with the electricity consumed on farm), and animal emissions (Equation 7). Fuel use emissions could be calculated based on information provided in nutrient management planning, such as fertilizer application timing and crop acreage and harvest. Additionally, the calculation requires consideration of the type of equipment being used on the farm (e.g. equipment for harvesting crops, feeding animals, etc.), farm records on heating and electricity, and information on how electricity was generated. Animal emissions could be calculated as animal heads/farm.

Equation 7:

$$Farm\ C\ emissions\ [lbs\ CO_2 eq\ yr^{-1}] = \ fossil\ fuel\ emissions\ + \ animal\ emissions$$

We suggest initially omitting the GHG emissions associated with soil management (e.g., emissions differences from manure injection versus spraying) due to uncertainty and complexity of these measurements. In addition, these soil management emissions are being accounted for in part by SOC sequestration described below. This requires further consideration because soil management accounted for an estimated 52% of direct GHG emissions from agricultural activities in 2016.[43] Furthermore, Equation 7 also does not account for manure management (e.g., GHG emissions associated with storage of manure in anaerobic lagoons), which reportedly accounted for 15% of direct GHG emissions from agricultural activities nationwide in 2016.[44] Future work should examine

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[42] A hypothetical tradeoff between sequestration and emissions is if a farm increased its herd size and spread more manure on its fields, it could feasibly increase field C storage yet still have a net increase in C emissions from farm operations. In our measurement design, this scenario would not be eligible for payment.

[43] Congressional Research Service. 2018. Greenhouse gas emissions and sinks in US agriculture. www.crs.gov

[44] Congressional Research Service. 2018. Greenhouse gas emissions and sinks in US agriculture. www.crs.gov

including these components. It is worth noting that some tools for calculating C emissions, such as the Cool Farm[45] tool and COMET-farm[46] tool have existing platforms that could be used to calculate GHG change using practice-based models.

Field C sequestration

Field C sequestration for each field can be calculated from the change in soil organic C (SOC) stock and perennial biomass C (PBC) stock. The SOC stock can be calculated from field soil samples using widely accepted equations.[47] Perennial biomass C (PBC) represents trees and shrubs that are part of buffer strips or perennial crops (like apple trees), and can similarly be calculated using relatively simple and widely accepted equations.[48] Further development of the carbon portion of a PES program should also consider the permanence of the C sequestered and tradeoffs associated with N_2O and methane emissions.[49]

Equation 8: $Field\ C\ sequestration\ [lbs\ CO_2eq] = \Delta SOC\ stock + \Delta PBC\ stock$

4.3. Data management and standards

Managing data (e.g. collection, storage, privacy, etc.) is a critical element of any PES program. We recommend that the PES have a single data entry platform, which participants or program administrator use to enter the information needed for the calculation of each metric. A single software platform would ensure consistency and standardization of necessary data and calculations. The PES platform should be designed to maximize farmer access, ideally streamlining data collection and entry for the PES with existing tools for nutrient management planning.

Currently there are numerous existing computer software platforms that can calculate ES metrics as shown below in Table 1. UVM Extension has developed goCrop™ to help farmers complete nutrient management plans, and goCrop™ holds much of the

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[45]Cool Farm Alliance. Cool Farm Tool https://coolfarmtool.org/ retrieved: 6/13/2019

[46] National Renewable Energy Lab, Colorado State University and USDA. COMET-farm http://cometfarm.nrel.colostate.edu/ retrieved: 6/13/2019

[47] The SOC stock can be estimated from bulk density, SOC content and A-horizon or tilled layer thickness (z). For more information on these methods see Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., ... & Niggli, U. (2012). Enhanced top soil carbon stocks under organic farming. *Proceedings of the National Academy of Sciences*, *109*(44), 18226-18231.; VandenBygaart, A. J. (2006). Monitoring soil organic carbon stock changes in agricultural landscapes: issues and a proposed approach. *Canadian Journal of Soil Science*, *86*(3), 451-463.; [47] Konen, M. E., Jacobs, P. M., Burras, C. L., Talaga, B. J., & Mason, J. A. (2002). Equations for predicting soil organic carbon using loss-on-ignition for north central US soils. Soil Science Society of America Journal, 66(6), 1878-1881.

[48] The PBC stock can be calculated as a function of aboveground metric (e.g. trunk diameter at breast height) and the plant species or community type, such a function is called an allometric equation. For more information on these methods, see Van Breugel, Michiel, Johannes Ransijn, Dylan Craven, Frans Bongers, and Jefferson S. Hall. "Estimating carbon stock in secondary forests: decisions and uncertainties associated with allometric biomass models." *Forest ecology and management* 262, no. 8 (2011): 1648-1657.

[49] Powlson, D. S., Whitmore, A. P., & Goulding, K. W. (2011). Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *European Journal of Soil Science*, *62*(1), 42-55.

information needed for the above proposed calculations. We see goCrop™ as promising platform that could interface with ecosystem service software to streamline farmer reporting for program requirements.

Whatever the platform, we suggest that all farm level data and metrics should remain anonymous and private. Additionally, the program should provide ample support and resources for farmers to assist in collecting and reporting data. Program staff have an important role to play in providing upfront technical assistance to participants in planning for program participation and training farmers in use of the program data management platform. We envision that farmer participants will input data into the program platform annually. Program staff would then review participant annual reporting to verify reductions and perform on-farm inspections at least once a contract period to further verify implementation of farm management changes and levels of ecosystem service provisioning.

Table 1. A non-exhaustive list of tools for farm scale evaluation of environmental impacts and ecosystem services

Tool	Impact or Service	Input Data	Interface - Platform	Developer
Vermont P Index[50]	P loss to waterways from fields	Soil Test P, RUSLE, manure, field geometry, etc...	Microsoft Excel Spreadsheet	University of Vermont Extension
Whole Farm Nutrient Balance[51]	Farmgate surplus or deficit of nutrients	Sales and Purchases of Feed, Fertilizer, Food and Animals	Worksheet or Desktop software	Cornell University Nutrient Management Spear Program
goCrop™ [52]	Vermont P Index and Whole Farm Nutrient Balance	See above	Online Tool	University of Vermont Extension
FarmPREP[53]	P load reduction to waterways	Practices on Farm Field Polygons	Online Tool - APEX	Stone Environmental
COMET-Farm and COMET-Energy[54]	GHG emissions associated with fuel and land use	Land use, practices equipment operations	Online Tool	USDA NRCS Colorado State University
Cool Farm Tool[55]	GHG emissions associated with fuel and land use	Land use, practices equipment operations	Online Tool	Cool Farm Alliance
Rapid C Assessment (RaCA)[56]	Soil organic C stock	Bulk density, total C, calcium carbonate C	Microsoft Excel Spreadsheet	NRCS
Resource Stewardship Evaluation Tool[57]	Multiple Environmental Impacts Including Water Quality and GHGs	Varies Depending on Impact	Online Tool - Combines Multiple NRCS Tools, including COMET	NRCS

[50] UVM Extension. Vermont P Index. https://www.uvm.edu/extension/agriculture/vermont-phosphorous-index retrieved: 6/13/2019

[51] Cornell University. Whole Farm Nutrient Balance. http://nmsp.cals.cornell.edu/projects/curriculum.html retrieved: 6/13/2019

[52] UVM Extension. goCrop software. https://gocrop.com/ retrieved: 6/13/2019

[53] Stone Environmental. FarmPrep https://farm-prep.net/info retrieved: 6/13/2019

[54] National Renewable Energy Lab, Colorado State University and USDA. COMET-farm http://cometfarm.nrel.colostate.edu/ retrieved: 6/13/2019

[55] Cool Farm Alliance. Cool Farm Tool. https://coolfarmtool.org/ retrieved: 6/13/2019

[56] NRCS. Rapid Carbon Assessment https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054164 retrieved: 6/13/2019

[57] NRCS. Resource Stewardship Evaluation Tool. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/cp/?cid=nrcseprd429509 retrieved: 6/13/2019

5. PAYMENT STRUCTURE

In this section we address the following aspects of a PES payment structure for P retention and C sequestration in Vermont: ecosystem service units (i.e., defining the units for which payments are made), timing of payments, amount of payments, funding source(s), transaction logistics and an estimate of the overall cost of the program. Again, this section focuses mainly on payments for P and briefly mentions payments for C sequestration. However, we end this section with a discussion of how payments for multiple services could be combined in the event that funding is secured for P and C services, or even others.

5.1. Payment basis

We propose to use the value for annual P load (lbs P yr^{-1}) from a farm as the basis for P payments. This value is arrived at by summing the two proposed P metrics (shown in Equation 1 in the previous section). Likewise, we propose to use the value for net annual C emissions (lbs CO_2eq yr^{-1}) year as the basis for C payments, which is the sum of the two proposed C metrics (shown in Equation 6). In order to calculate a payment, we compare a farm's annual P load or C emissions with a baseline value for a given farm to determine the P or C benefit (Equation 9). The program would then pay the farmer for this annual P and/or C benefit, or the change in P (ΔP) and/or C (ΔC).

Equation 9: $\Delta P = (P \text{ in year } X) - (\text{Baseline } P)$

Setting the baseline P load and C emissions for measurements is a critical element of a performance-based PES design and can be approached through a number of different strategies. The way the baseline is set will determine which farmers benefit and how much they might be paid. We recommend that the approach to setting a baseline be decided upon through a collaborative process that balances the goals of program administrators and stakeholders. To address farmers' concerns about equity, it is essential that this process highlights and respects farmers' perspectives on the structure of payments and the baseline.

We suggest here three different possible baseline strategies as a starting point for a conversation. We describe these from the perspective of a P load baseline, but they are also compatible with a C emissions baseline (except for #3, as there are no regulatory requirements for C emissions on farms):

1. *Baseline P load of the year prior to entering the program*: Baseline P load is calculated for a farm entering the program using data from the single year prior to entering the program.
2. *Baseline at average P load of three years prior to entering program*: Baseline P load is calculated for a farm entering the program using data from the three years prior to entering the program. The average P load for the three years is used as the baseline to calculate ΔP. This baseline approach is illustrated below in Figure 3.

3. *Baseline at RAP compliance*: Regardless of the current practices or management strategies on the farm, the baseline is set at the RAP regulatory requirements for a given farm.

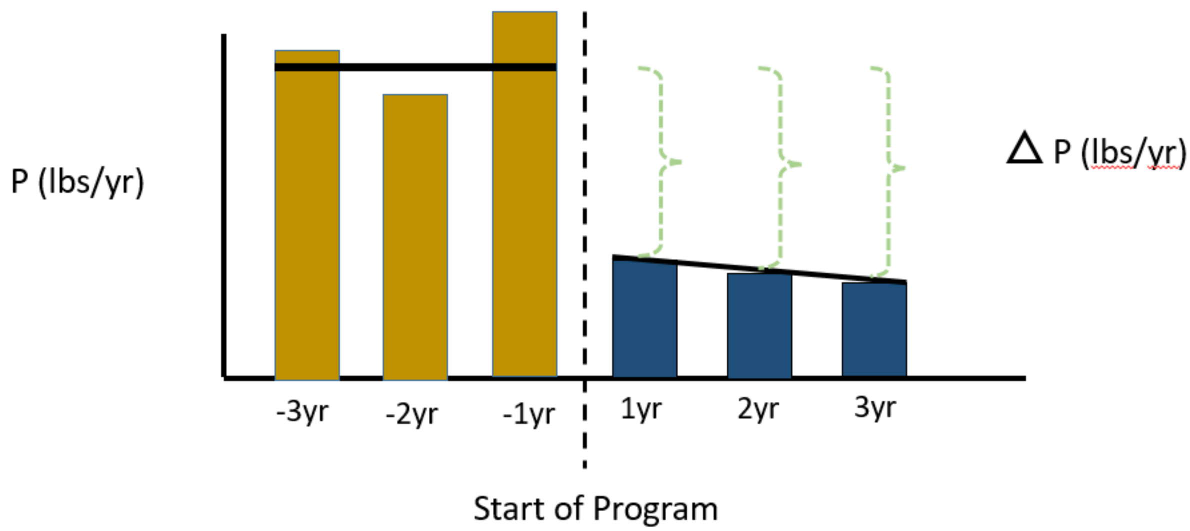

Figure 3. Illustration of calculating P benefit from a farm using baseline P load as average P load three years prior to entering program. The green dashed lines represent the annual change in P that would be paid for by the programs.

There are several other approaches, beyond these three, that could be used to set the baseline for payments in the program. Another potential alternative approach for a P load baseline, but more complex to implement, would be to estimate each farm's portion of the TMDL P load reductions for agriculture in a given sub-watershed and then pay farmers for contributing, beyond their RAP requirements, to achieving the sub-watershed's TMDL goals. This assumes that the RAP requirements will not achieve the full amount of P load reduction required under the TMDL in some sub-watersheds. Furthermore, it would give individual farms' the ability to quantify their direct contribution to meeting the state's TMDL goals. Additionally, it should be noted that the P load and C emissions baseline do not necessarily need to be set using the same approach.

The approach used to set an annual baseline P load or C emissions is a challenging decision because it has important consequences for the additionality and equity of the program. For example, if a baseline is set to consider just the P load of the one year prior to the program this could disincentive those who have recently made improvements (e.g. made changes three years prior) from participating in the program because they would not be paid for the impact of their recent improvements. Furthermore, it could encourage farmers to increase their P load prior to enrolling in order to achieve greater payments in the program. However, setting the baseline in a way that allows farmers to be paid for previous improvements creates questions over whether P reductions attributed to the program are actually due to the program. For example, by setting the baseline at RAP compliance, farmers who have already made improvements beyond regulatory requirements could be paid for improvements made before the PES program started. These prior improvements would not be a result of the program. We discuss these considerations more fully in Section 6.

5.2. Payment amount

We recommend paying farmers for each pound of P and/or C reduced on an annual basis compared to the baseline (e.g., ΔP in pounds P in Equation 9). We propose a preliminary range for a price per pound P reduction, but we caution against using these values without further research. At this point, we do not suggest a preliminary payment amount per pound C, and therefore do not consider C sequestration in this section. The price per pound P and C offered is another critical consideration for program design because it is the core incentive offered by the program. Setting the price right enables the desired level of farmer participation and ecosystem service outcomes.

Based on our research, an appropriate range for a base rate payment per pound P load reduction appears to be between $10 and $100. A recent white paper on "pay-for-performance conservation" gives a number of examples of payments for P reduction programs that offered payments ranging from $10 to $30 a pound.[58] This report mentions that a pilot test was run for a PES program in a Lake Champlain sub-watershed from 2006-2010 that included an incentive payment rate at $25 per pound P. The authors also present a cost-effectiveness analysis of P load reduction actions on Wisconsin Farms used to determine a $25 per pound P payment for P reduction in a PES program. The cost effectiveness analysis looked at a number of BMPs, including cover crops, tillage, contouring, nutrient management, filter strip and crop rotation, and determined that at a price of $25 per pound P many BMPs would be incentivized. However, it also found that more expensive BMPs per pound, such as crop rotation and cover crops are less likely to be incentivized through the program at the price of $25 per pound P.[59] As suggested by this example, establishing a set price per pound for P would likely incentivize management changes that are most cost effective for farmers, and perhaps leave room for farmers to innovate towards the goal of P load reduction. Based on NRCS calculations, "ditch buffers and crop rotations are the most cost effective practices in reducing P losses ($2 and $35 per pound of P), while the farmstead practices are the least cost effective at over $5,000 per pound of P."[60] Another estimate for price per pound P reduction comes from the organization Newtrient, which suggested that $100 per pound P may be an appropriate estimate for covering the cost of achieving P reduction solutions from agriculture.[61] We take these examples to suggest that a likely that the base rate payment for pound P for a PES for Vermont lies in the range of $10 to $100. However, we want to be clear that more

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[58] Fisher et al., 2017.

[59] Fisher et al., 2017.

[60] Resource Assessment and Watershed Level Plan for Agriculture in the St. Albans Bay Watershed, Franklin County, Vermont. USDA/NRCS. May 2016.

[61] Newtrient LLC, "Dairy Sustainability Alliance Webinar: Ecosystem Services Markets (ESM): What Are ESMs and How Can They Benefit Dairy?," 2019, https://www.newtrient.com/Blog/Webinar-Dairy-Sustainability-Alliance---Ecosystem-Services-Markets.

analysis is needed to determine the appropriate base rate payment and the types of behaviors that the payment is most likely to incentivize.

Once a base payment is decided upon, we propose to differentiate payments per pound P reduction to participants based on farm size and farm location, in order to incentivize participation among farms of all sizes and to target participation by farmers in TMDL-priority watersheds. Under this payment differentiation, smaller farms would receive higher payments than larger farms to account for the larger marginal abatement costs they face (i.e., the same management actions often cost less for larger farms to implement because they can take advantage of economies of scale). This mechanism decreases the economic efficiency of the program, but enhances equitability in the distribution of benefits by encouraging enrollment from a diversity of farm sizes. In addition, farms located in sub-watershed with high TMDL load reduction requirements would receive higher payments than farms located in watersheds with lower reduction requirements. For example, farms in the Missisquoi River watershed are targeted over farms in the Winooski River watershed because farms in the Missisquoi River watershed face much higher P reduction requirements under the TMDL than farms in the Winooski River watershed. Targeting our payments to prioritize participation from farms within these watersheds aligns the PES with Vermont's water quality needs and efforts to achieve the TMDL. For C sequestration, payments would only be differentiated based on farm size, as TMDL priority sub-watersheds are not relevant to C sequestration goals.

It is worth noting that designing payments around a price per pound of P reduction is not the only potential approach, and that an alternative approach is to use procurement auctions. In a procurement auction, farms would submit a bid to provide a given level of P load reduction or C sequestration for a given period of time at a given price. The program administrators would then select from among the bids those that they find to best meet the PES program needs, such as the most P load reduction for the lowest price or based on farm size and location.[62] An existing example of a procurement auction style PES is the USDA's Conservation Reserve Program in which farmer's bid to receive payments to take agricultural land out of production, a program that is familiar for most US farmers. The benefit of an auction approach is that it theoretically allows for greater efficiency of program spending (e.g. more P load reduction per program dollar)[63], but the pricing of payments is transparent to program participants. We suggest that both a price per pound approach and a procurement auction approach be considered in conversations amongst stakeholders around the PES program design.

5.3. Enrollment eligibility

In order to be eligible to participate in the PES program, we propose that farms would need to be compliant with the RAPs. This mitigates the potential for participants to use

[62] An auction-based approach to payment allocation would remove the need to differentiate prices, but could instead give higher weights to bids based on farm size and location

[63] Latacz-Lohmann, U. and Van der Hamsvoort, C. (1997). *Auctioning Conservation Contracts: A Theoretical Analysis and an Application.* American Journal of Agricultural Economics.

PES program dollars to achieve regulatory compliance. At this point, we do not foresee eligibility requirements related to C sequestration.

5.4. Payment schedule

We recommend that a PES for Vermont have an annual payment schedule with a 2-3 year renewable contract. While longer contracts may in theory be preferable, it will likely be difficult to ensure funding over longer periods of time. An important question to consider for program implementation is what happens to the baseline for farms that re-enroll. Two potential options are: 1) the baseline does not change or 2) the baseline is reestablished based on the average performance over the past 3-5 years. This is another controversial question and best decided in collaboration with participants and stakeholders.

At the time of enrollment, we also recommend that participants be offered an upfront payment to provide financial support for implementing new practices requiring capital investment. These initial payments would also minimize the risk borne by farmers implementing innovative practices that may not yet be proven to minimize P or improve C sequestration. After the initial upfront payment, farmers would receive annual payments based on their change from baseline.

5.5. Funding source

We recommend a third-party financing mechanism for a PES scheme in Vermont, in which a third-party serves as a single buyer that purchases P and C on behalf of the public. Third-party financing is one of three general categories for financing options within a PES scheme. The other two categories are user-financed funding and compliance PES, as shown in Table 2 below.[64]

Table 2. Financing mechanisms for PES [65]

Third-party funding	User-financed funding	Compliance PES
Government or third party purchases the ecosystem service on behalf of the public and/or direct users.	Beneficiaries directly pay ecosystem service providers.	Participants with regulatory requirements purchase offsets or credits from others to meet requirement for regulations

Both third-party financing and user-financing are popular forms of funding for watershed-based PES.[66] However, user-financed PES typically rely on a strong

[64] Salzman, J., G. Bennett, N. Carroll, A. Goldstein, and M. Jenkins. "The Global Status and Trends of Payments for Ecosystem Services." *Nature Sustainability* 1, no. 3 (2018): 136.; OECD, "Scaling-up Finance Mechanisms for Biodiversity," 2013, https://doi.org/http://dx.doi.org/10.1787/9789264193833-en

[65] Salzman, J. et al., 2018.

[66] Salzman, J. et al., 2018.

relationship between downstream water users and upstream land owners to enable the transfer of payments.[67] In Vermont this condition would be difficult to meet because numerous watersheds need to reduce P transport under the TMDL.[68] This is the same reason that a compliance-based PES, where parties purchase offsets from others in order to meet regulatory requirements, is unlikely (e.g. if all parties need to reduce, than it is unlikely that some could purchase their required reduction from others). The PES needs to operate across many different watersheds with different types of upstream/downstream dynamics in each. For C sequestration PES, user-financed PES are rare[69] because this upstream/downstream relationship does not exist for C. The benefits of C sequestration are global. Therefore, we recommend a third- party financing structure as the most feasible mechanism to pay farmers to provide ecosystem services.

A third-party system also allows flexibility for diverse funding sources to be combined. A combination of public state funds, federal funds and funding from non-profits or the private sector could be pooled and managed through an intermediary. This both streamlines transaction costs for multiple ecosystem services and simplifies the interface for farmers who participate in the program. This kind of combined funding effort has been applied to programs with similar goals, such as Costa Rica's national PES program.[70]

Public funds dedicated to meeting the state's agricultural TMDL goals are well poised to finance the water quality aspects of a Vermont PES for the public benefit. This could manifest in the form of an expansion of the existing Vermont Clean Water Fund,[71] or a new independent fund. Vermont Clean Water Fund dollars are already being used for important financial incentives, technical assistance and conservation easements that support farmers in making changes to both achieve regulatory requirements and go beyond for water quality. This state level work complements federally funded efforts undertaken by the NRCS to support Vermont agriculture's water quality goals. NRCS programs in Vermont have also targeted TMDL priority sub-watersheds to help achieve watershed level P reduction goals. For example, NRCS analysis found that their incentive program could support 35% of the watershed TDML reduction goals (8,066 lbs) in St. Albans Bay over five years in partnership with a local watershed team at a

[67] S. Wunder, "Payments for Environmental Services: Some Nuts and Bolts," 2005, https://vtechworks.lib.vt.edu/handle/10919/66932.

[68] EPA, "Phosphorus TMDLs for Vermont Segments of Lake Champlain, June 17, 2016."

[69] Salzman, J. et al., 2018.

[70] Blackman, A., and R. T. Woodward. "User Financing in a National Payments for Environmental Services Program: Costa Rican Hydropower." *Ecological Economics* 69, no. 8 (2010): 1626–1638.

[71] The Vermont Clean Water Fund consists of funding allocated for achieving the Vermont TMDL for Lake Champlain. Given that this proposed PES would reduce phosphorus loads to Lake Champlain, it would contribute toward Vermont achieving its TMDL target.

total cost of $8,150,949.[72] This proposed PES would complement these programs by providing a mechanism for farmers to reduce P beyond RAP compliance and outside the limits for NRCS funding. A stable, long-term funding source is essential for a PES program to provide long-term benefits, and the Vermont Clean Water Fund, or similar state fund, would provide this certainty and stability.

It is important to note that this funding would mostly likely only contribute to paying for P reductions in the PES, and not C. At this point, there is not a clear funding stream for C sequestration services on farms in Vermont. For this reason, we have not developed a specific proposal to pay for C sequestration, but instead are building the foundation for C payments to be included in the future. If Vermont passes a C tax, or similar legislation, this could provide a potential funding source for the PES. California has already created a program to pay farmers directly for sequestering C in agricultural soils[73], and there is currently great interest in bringing agricultural soils into C markets.[74] When there is a sound methodology for adding agricultural soils to existing C markets, it is likely that this can be a funding opportunity for payments for C in the Vermont PES. It is possible that the Vermont PES could provide access to C markets by serving as an intermediary to aggregate C credits, for farms that would not be able to access markets on their own. Once a funding stream becomes viable for C sequestration on farms, the PES program would be able to accommodate it via the structure proposed herein.

5.6. Funding intermediary

We recommend identifying a non-governmental organization, trusted by the farming community to administer the PES trust on behalf of the public. An intermediary will also need to have a working relationship with parallel projects such as the Vermont AAFM and Vermont DEC. A commitment to collaboration and strong facilitation of combined efforts among these organizations will be critical to the success of a program. Existing organizations, like the Vermont Housing and Conservation Board, UVM Extension, or the Vermont Land Trust have established relationships with farms, experience in providing technical assistance and administering agricultural management incentive programs and thus are well poised to take on administration of a Vermont PES.

Alternatively, a new organization could be set up with the single purpose of administering the PES. An example of this option can be seen in the PES portion of the Lake Taupo, New Zealand water quality policy. The Lake Taupo Protection Trust was created with a board of 8 appointed individuals to administer the purchasing of nitrogen

[72] Resource Assessment and Watershed Level Plan for Agriculture in the St. Albans Bay Watershed, Franklin County, Vermont. USDA/NRCS. May 2016.

[73] Healthy Soils Program, Office of Environmental Farming and Innovation, California Dept. of Food and Agriculture. https://www.cdfa.ca.gov/oefi/healthysoils/

[74] Engel, S. and Muller, A. (2016). *Payments for environmental services to promote "climate-smart agriculture"? Potential and challenges.* Agricultural Economics.; Vermeulen, S. et al. (2019). *A global agenda for collective action on soil carbon*. Nature Sustainability.

credits on behalf of the New Zealand public, using government funds.[75] A similar trust board could be created with members from the public, farmers, scientists and government officials to serve as an independent body to administer Vermont's PES. In a series of recent focus groups, Vermont farmers expressed a desire to see a new organization outside of regulator's purview to serve as an intermediary for a PES program.[76] However, given the great number of NGOs and governmental bodies operating on issues relating to water quality and C sequestration, we suggest building the PES upon existing institutional infrastructure and relationships.

5.7. Program cost

To examine the program cost for a P reduction PES for Vermont, we first frame the cost analysis from the perspective of using the PES to make a meaningful contribution to meeting the Lake Champlain Basin TMDL. We again focus only on the P portion of the program, as we do not have price estimates for C to form the basis for a program cost estimate. Examining the documentation and analysis that went into creating the TMDL figures for the agricultural load, in particular the BMP Scenario Tool,[77] it is clear that it will be very difficult to achieve the required P load reduction from the agricultural sector through regulatory requirements alone in some of the more polluted watersheds. It would require near universal adoption of BMPs, which is not necessarily required by the RAPs.[78] An important information gap for Vermont to achieve the TMDL, and an important consideration in the program design for this PES, is the actual load reduction expected to be achieved through RAP implementation and other TMDL efforts in each of the Lake Champlain sub-watersheds. If we had this figure, we could examine what it might cost to cover this additional and remaining portion of the P load reduction that will not be achieved through current efforts. Absent this figure, we can instead examine scenarios in which the PES achieves 10%, 20% or 30% of the agricultural P load reduction in the five sub-watersheds with the highest P load reduction requirements under the TMDL. The five sub-watersheds, with their required agricultural P load reduction under the TMDL are:

- Missisquoi Bay: 45 mt P yr^{-1}
- Otter Creek: 31 mt P yr^{-1}
- South Lake A: 14 mt P yr^{-1}
- Main Lake: 14 mt P yr^{-1}

[75] Yerex, S. (2009) "Protecting Lake Taupo: The Strategy and the Lessons." http://www.laketaupoprotectiontrust.org.nz/page/lake_53.php

[76] White, A., Faulkner, J., Conner., D and Mendez, E. (2019). [Focus groups with Vermont farmers about Ecosystem Services]. Unpublished raw data.

[77] Inc. Tetra Tech. 2018. "Lake Champlain BMP Scenario Tool: Requirements and Design" Boston, MA.

[78] Tetra Tech., 2015.; Zia, A., Bomblies, A., Schroth, A., Koliba, C., Isles, P., Tsai, Y., Mohammed, I., Bucini, G., Clemins, P., Turnbull, S., Rogers, M., Hamed, A., Beckage, B, Winter, J., Adair, C., Galford, G., Rizzo, D., and Van Houten, J., 2016. Coupled Impacts of Climate and Land Use Change Across a River-Lake Continuum: Insights from an Integrated Assessment Model of Lake Champlain's Missisquoi Basin, 2000-2040. *Environmental Research Letters.* 11(11).

- South Lake B: 12 mt P yr^{-1}

With these figures, we can then examine the aggregate P load associated with a 10%, 20% or 30% reduction in agricultural P load in each of these watersheds, which ranges from 12 mt $yr^{-1}$to 35 mt yr^{-1} (Table 3). Converting these values into P lb yr^{-1}, we can then apply our proposed range of prices for P lbs yr^{-1} for a Vermont PES (Table 3), to suggest a ballpark estimate of what this program might cost to achieve a meaningful contribution to the Lake Champlain TMDL. Our estimates suggest that on the low end, to achieve a 10% reduction in agricultural P loading from these five watersheds at a cost of $10 lb P yr^{-1}, would cost $260,000. On the high end, we estimate that to achieve a 30% reduction in agricultural P loading from these five watersheds at a cost of $30 lb P yr^{-1}would cost $7,800,000 annually.[79]

Table 3. Annual Cost estimates for a PES for Vermont to achieve Agricultural P load reduction scenarios from five key sub-watersheds (South Lake B, South Lake A, Otter Creek, Main Lake and Missisquoi Bay)

P load reduction scenarios	10% reduction	20% reduction	30% reduction
P load (mt yr^{-1})	12 mt yr^{-1}	23 mt yr^{-1}	35 mt yr^{-1}
P load (lb yr^{-1})	26,000 lb yr^{-1}	52,000 lb yr^{-1}	78,000 lb yr^{-1}
$10/lb P	$260,000	$520,000	$780,000
$25/lb P	$650,000	$1,300,000	$1,950,000
$100/lb P	$2,600,000	$5,200,000	$7,800,000

5.8. Payment structure for multiple services

One of our main program objectives, listed above in Section 3, is to pay farmers for multiple ecosystem services. This is in part because farms are already producing multiple ecosystem services and paying for multiple services allows for farmers to take advantage of co-benefits between services. Paying for multiple services will also provide additional economic benefit to farmers and may be the extra incentive needed to make some management changes feasible. While we have mostly focused on how to structure our proposed program for P reduction measurement and payments, here we suggest how payments could be combined for multiple ecosystem services.

The key consideration in designing a PES to pay for multiple services (i.e. P reduction and C sequestration) generated simultaneously from a farm is how payments incorporate the contribution of each service into the payment. The two primary methods for this are bundling and layering.[80] In layering, services are paid for separately, which avoids the difficult task of weighting relative contribution of each service to a payment. In a bundling approach, the provisioning of multiple services is combined into one

[79] Note that these estimates are for the P payments portion of the program and not for administrative or other program costs.

[80] Smith, S., P. Rowcroft, M. Everard, L. Couldrick, M. Reed, H. Rogers, T. Quick, C. Eves, and C. White. "Payments for Ecosystem Services: A Best Practice Guide." *Defra, London*, 2013.

payment. We suggest layering payments because it avoids the challenge of weighting the unique contribution of P and C to payments. Since we have not identified a funding source for C sequestration in Vermont currently, this proposed PES could start by paying farmers for P reduction, and then layer C payments on top of the P payments if and when funding is secured.

Furthermore, layering makes it easy to add additional services to the program as funding becomes available. A promising third ecosystem service to consider in the future for this program is flood mitigation services. Many researchers and NGOs within Vermont are working on this issue and in particular on quantifying floodplain and wetland restoration services.[81] It is possible that, given a funding source and appropriate measurement models, the PES could pay for flood mitigation services provided by agricultural lands.

It is important to note that a layering approach doesn't consider tradeoffs in provisioning of each of the services. For example, a farm could change land management such that P retention is increased, but C sequestration is decreased. In a bundled approach, the overall payment would be decreased, or even no longer available, while in a layered approach, the farmer could still receive payment for P retention, even if it were achieved at the expense of C. Requiring farmers to achieve RAP compliance to be eligible for the program should help to alleviate these tradeoff concerns.

[81] Singh, Nitin K., Jesse D. Gourevitch, Beverley C. Wemple, Keri B. Watson, Donna M. Rizzo, Stephen Polasky, and Taylor H. Ricketts. "Optimizing Wetland Restoration to Improve Water Quality at a Regional Scale." *Environmental Research Letters* 14, no. 6 (May 2019): 064006. https://doi.org/10.1088/1748-9326/ab1827.;."; 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.; The Nature Conservancy and Gund Institute for Environment. "Nature-based solutions for Vermont."

6. Critical Considerations

We now turn to some critical considerations common to most PES programs. We examine how the program we have proposed performs along the lines of additionality, permanence, leakage and equity.

6.1. Additionality

In the context of a PES, as mentioned above in Section 2, additionality refers to the provisioning of ecosystem services that would not have occurred without a PES incentive.[82] PES program efficacy and efficiency is often assessed in terms of additionality, generally at the level of each individual participant. Considering additionality allows programs to target participants for whom payments would result in the greatest amount of additional ES protection or provisioning relative to the status quo. Demonstrating additionality within a PES scheme is often motivated by a desire to reassure investors, buyers or downstream beneficiaries that the payment program is achieving desired outcomes in the most effective and economically efficient way possible.

For a Vermont PES, this translates into the P load reduction or C sequestration that we can claim is due to the program. Given the history and complexity of water quality and agricultural regulations in the state, consideration of the existing regulatory landscape is particularly important in assessing program additionality in the context of water quality in Vermont. Accordingly, we propose that payments target P reduction beyond those resulting from practices required by RAPs in accordance with the TMDL set by the state. This ensures that payments are achieving additional reductions, and therefore provisioning of ES, beyond what would happen in a no-incentive, status quo scenario.

Pursuit of additionality can have implications for perceived fairness and therefore program participation and program success (see equity section below for further discussion). To address these issues, we propose layered and differentiated payments, which extend opportunities for program participation, attempt to equalize the farmer livelihood impacts of participation and target areas of greatest concern from a water quality standpoint. Our hope is that this makes participation beneficial to farmers for whom P reduction payments will be less impactful; for example, farmers who live far from areas of greatest water quality concern but may eventually be able to participate in the program through C sequestration. Differentiated payments, meanwhile, are designed to address a number of equity considerations. For example, differentiated payments address differential implementation costs of P reduction by weighting payments based on farm size, as well as differential impacts of P reduction in spatially targeted priority watersheds. By expanding and weighting the distribution of payment benefits, layered and differentiated payments may increase program participation that could otherwise be undermined by perceived unfairness. Increased participation, in turn, increases program additionality.

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[82] J Börner et al., "The Effectiveness of Payments for Environmental Services," *Elsevier*, accessed June 11, 2019, https://www.sciencedirect.com/science/article/pii/S0305750X17300827.

Finally, the choice of a baseline for determining payments will have important implications for additionality, as mentioned in Section 5 above. For example, if we adopt a 3-year-averaged baseline, it is likely that the baseline will allow farmers to be paid for some portion of the work undertaken prior to the program (i.e. in the last three years) by farmers who have been leaders in addressing agricultural water quality issues. For example, if a farmer adopted cover cropping one year prior to entering the program, the baseline would be an average of the P load reduction from two years without cover cropping and one year with cover cropping. The farmer would then be paid for P load reduction relative to this averaged baseline, which means that the farmer would receive some payments associated with the load reduction due to cover cropping. However, this baseline approach would honor these efforts by leaders in the farming community by giving them at least partial credit for recent changes. We feel that this approach would strike a balance between equity and additionality by simultaneously addressing the goals of improved water quality and farm viability in Vermont.

It is important to acknowledge that in designing a Vermont PES around performance (as opposed to practices) and using differentiated payments, this program would benefit some farms more than others. We acknowledge that this payment scheme may fail to fully compensate farmers who have been leaders in implementing best practices for reducing P loading to waterways. However, our proposal offers a pragmatic path forward given that funding for achieving the TMDL is limited.

6.2. Permanence

Another important aspect of PES schemes is their permanence, or the extent to which provisioning of targeted ecosystem services persists into the future. The concept of permanence highlights the tension between a buyer's desire that ecosystem service not be "lost" or reversed in the future, and an ecosystem service provider's preference for short-term, low-risk engagement. Given the legacy effect of P in the state's lakes and ponds, permanence is particularly relevant in the context of a PES scheme designed to improve water quality in Vermont. Unfortunately, determinants of permanence remain poorly understood.[83]

One factor that has been found to increase the likelihood of permanence in the event that payments cease is the nature of provisioning that occurs due to a PES scheme. For example, asset- or capacity-building mechanisms (e.g., productive uses of land like cover cropping or manure injection) for provisioning have been found to persist after payments cease; technical support in implementing such mechanisms may also contribute to permanence.[84] This provisioning approach stands in contrast to damage prevention approaches (e.g., land retirement), which are often easier and less costly for

[83] Börner et al., 2019.

[84] S. Pagiola, J. Honey-Rosés, and J. Freire-González, "Evaluation of the Permanence of Land Use Change Induced by Payments for Environmental Services in Quindío, Colombia," ed. Chris T. Bauch, *PLOS ONE* 11, no. 3 (March 1, 2016): e0147829, https://doi.org/10.1371/journal.pone.0147829.

landowners or land users to abandon or reverse. Our program proposal adheres to an asset- and capacity-building approach by encouraging farmers to innovatively implement the practices, systems and/or technologies that most efficiently enable them to measurably reduce P loading to surface water. Furthermore, by utilizing P accounting programs that are designed and/or supported by UVM extension, our proposal encourages farmers to seek technical support from trusted advisors. Overall a transparent, collaborative and dynamic approach to program design and implementation will be key in achieving permanent improvements in a PES for Vermont.

6.3. Leakage

PES programs may result in leakage effects that reduce their efficiency. In our case, leakage effects refer to the intensification or extensification of agricultural practices in locations where payments are not received, effectively exporting P loading or C emissions.[85] For example, Wu[86] (2000) showed that for every hundred acres of cropland retired under the Conservation Reserve Program, twenty acres of non-cropland were converted to cropland elsewhere in the central United States. Leakage is often the result of short-term decreases in agricultural production increasing the price of agricultural products, thereby incentivizing producers not enrolled in the program to intensify and expand production.[87]

In a Vermont PES program, we predict that leakage effects are unlikely. Given that Vermont farmers currently operate within a global agricultural market, where prices for agricultural products are controlled by factors outside of Vermont's control, it is possible that any changes in production that result from implementation of a PES program would not alter commodity prices. As agricultural commodity prices are not strongly responsive to changes in Vermont's production, then leakage effects would be minor to non-existent.

6.4. Equity

Historically, economic efficiency has been the primary indicator of success for PES programs, and only secondarily have equity and social impacts been considered.[88] While there may be tradeoffs between social equity and economic efficiency, evidence indicates that considering social equity can actually improve program effectiveness. Positive attitudes towards governance and perceived fairness of a PES program are

[85] Patrick Meyfroidt et al., "Globalization of Land Use: Distant Drivers of Land Change and Geographic Displacement of Land Use," *Current Opinion in Environmental Sustainability* 5, no. 5 (2013): 438–44.

[86] JunJie Wu, "Slippage Effects of the Conservation Reserve Program," *American Journal of Agricultural Economics* 82, no. 4 (2000): 979–92.

[87] Farzad Taheripour, "Economic Impacts of the Conservation Reserve Program: A General Equilibrium Framework," 2006.

[88] Giulia Irene Wegner, "Payments for Ecosystem Services (PES): A Flexible, Participatory, and Integrated Approach for Improved Conservation and Equity Outcomes," *Environment, Development and Sustainability* 18, no. 3 (June 3, 2016): 617–44, https://doi.org/10.1007/s10668-015-9673-7.

associated with improved effectiveness[89] and compliance with regulations.[90] Conversely, inequity, whether perceived or actual, has the potential to create social and political instability, disincentivize cooperation and increase the likelihood of opposition to project implementation.[91] In designing our proposal, the main equity concerns we consider are: who has access to program participation, whether some participants benefit more than others in a way that contributes to socio-economic inequality, how farm size corresponds to access to land and capital in Vermont and how the proposed program may interact with the trend of farm consolidation and the nationwide decline of small farms.

We propose differentiated payments to address tradeoffs between efficiency and social equity. Under our proposed performance-based scheme where farmers are paid a constant price for per acre reductions in P, it is likely that large farms will disproportionately benefit. Due to economies of scale, larger farms are typically able to realize a lower per unit cost for P reduction, making it more efficient for payments to be directed toward these businesses. By attempting to address the likelihood that small farms will benefit less from program participation, our proposal seeks to rectify potential distributional and contextual equity concerns by weighting payments for P reduction based on farm size. In this way, our proposal strives to avoid contributing to processes of farm consolidation and extensification.

As noted previously, however, achieving necessary ecological outcomes with limited funding requires balancing equity and efficiency. To this end, we also differentiate payments by priority watersheds. This will clearly benefit farms in priority watersheds. We are aware that our proposal follows the trend of other regulatory and non-regulatory programs that have prioritized water quality funding for farms in the Lake Champlain Basin. We propose that this may be balanced in the long run once a funding source is identified for C and/or other ecosystem services. For C sequestration and beyond, our layered payment structure would provide opportunities for non-priority-watershed farms to seek payments.

Tradeoffs between equity and efficiency constitute some of the most important and difficult considerations within designing a PES program and will require continuous consideration throughout every phase of program design and implementation.

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[89] J. A. Oldekop et al., "A Global Assessment of the Social and Conservation Outcomes of Protected Areas," *Conservation Biology* 30, no. 1 (2016): 133–41.

[90] Nicole D Gross-Camp et al., "Payments for Ecosystem Services in an African Protected Area: Exploring Issues of Legitimacy, Fairness, Equity and Effectiveness," *Oryx* 46, no. 1 (2012): 24–33.

[91] Brian W Miller, Susan C Caplow, and Paul W Leslie, "Feedbacks between Conservation and Social-Ecological Systems," *Conservation Biology* 26, no. 2 (2012): 218–27.

7. NEXT STEPS

In this last section, we lay out what we envision as the next steps to move this proposed program design from concept to reality.

7.1. Stakeholder driven process

Designing and implementing a PES for Vermont requires the involvement and collaboration between a number of stakeholders. We envision this paper as a potential guide to be discussed and decided upon amongst such stakeholders.

In Table 4 we lay out a non-exhaustive list of primary, secondary and peripheral stakeholders that should participate in designing a PES for Vermont. We differentiate between types of a stakeholders to suggest differing levels of involvement in program design: primary stakeholders should be included in all stages of a Vermont PES design, additional stakeholders should be consulted during the design process and peripheral agents who have a stake in the program design should have room to voice their perspectives.

Table 4. Stakeholders and level of involvement in Vermont PES design and implementation.

Primary Stakeholders	Secondary Stakeholders	Peripheral Stakeholders
Potential funders (e.g. State policy-makers from the AAFM and ANR; Legislators)	Conservation Districts (e.g. Vermont Association of Conservation Districts)	Beneficiaries (e.g. non-farming public)
Farmers (e.g. Dairy; Diversified vegetable & berry; Livestock)	Agricultural market actors (e.g. Dairy cooperatives; Ben & Jerry's)	Private business interests in PES technology (e.g. Newtrient; Ag Resource Strategies; Optis)
Agricultural Advisors (e.g. UVM Extension; VHCB Farm Viability; NRCS)	Farmer organizations (e.g. Farmer Watershed Alliance, Champlain Valley Farmers Coalition, Connecticut River Farmer Alliance, Northeast Organic Farmers Association of Vermont, Vermont Vegetable and Berry Growers Association, Vermont Grass Farmers Association, Rural Vermont)	Environmental advocacy groups (e.g. Conservation Law Foundation, The Nature Conservancy)
PES & research expertise (e.g. Gund Institute, UVM)		

7.2. Address knowledge gaps

An important step in implementing this PES will be answering some fundamental and lingering questions. In terms of ecosystem service measurement, the relationship between legacy P accumulation in soils and P lost to water is not well understood, but is central for understanding how farm management impacts water quality. In order to accurately combine our farm nutrient mass balance P metric and field loss P metric, we first need a better estimate of how these metrics relate.

As we have acknowledged throughout the paper, with respect to C, our proposal is much less developed. We suggest that an additional working or research group should be tasked with fully developing the measurement and payment structures for the C portion of the PES. In particular, a PES for C working group should consider the appropriate measurement tools and platforms to employ in the PES, the inclusion of GHG emissions associated with soil and manure management and how to approach the question of the permanence of C sequestered in program design.

More broadly, the sensitivity and accuracy of models selected to estimate performance of management changes is also a central question that needs to be considered. Without testing this relationship and demonstrating results, farmers may decide that the program payback is too uncertain or risky, and may decide not to enroll. The models need to be sensitive to management changes for the program to incentive these changes. These questions should be investigated through case study analysis of carefully selected representative farms. In these case studies, we recommend that scenario analyses are run to examine how the recommended metrics would change in response to different categories of management changes, such as adoption of field practices, increases in efficiency and precision via new technology adoption or farm system transition. Ideal UVM collaborators for this research include the Gund Institute for Environment, the Rubenstein School, the Plant & Soil Science Department and Extension.

Additional questions central to program design and implementation relate to farmer program experience and cost. It is not clear what different management changes will cost farms and whether these costs will differ for farms of different sizes and operations. The loss of profit that may be associated with management or field changes, such as reductions in herd size or conversion of a field to a forest or wetland, should also be investigated. It is important to ensure that PES payments will adequately compensate farmers for these costs as well as promote farm viability, which is a central goal of this PES. It is possible that the range of likely estimates for P payments presented in the payments section above are not appropriate for compensating and incentivizing Vermont farmers. Therefore, we need further research to ensure that the price per unit of ecosystem service is set at a level that incentivizes the desired level of ecosystem service provisioning targeted by the program. We suggest approaching these questions through farmer surveys and focus groups, and the results of these efforts will inform an equitable payment rate for this PES. Again, ideal UVM collaborators for this include researchers at the Gund Institute for Environment, Extension, the Food Systems program, or Community Development and Applied Economics.

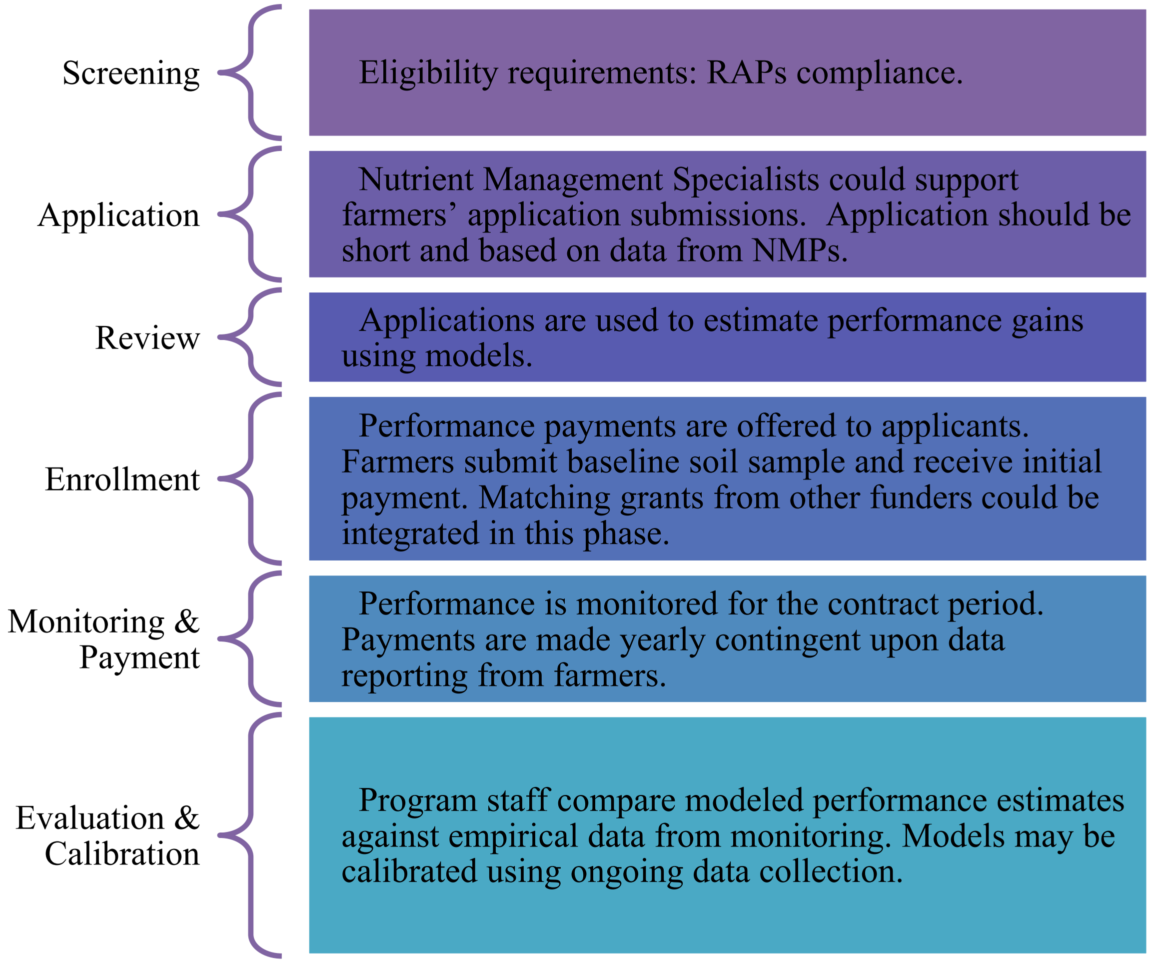
7.3. Develop a pilot program

We propose a pilot program as a second step of implementation. The pilot could include a small number of farms (3-6) with a variety of crop types, sizes and management choices. This basic structure would maximize diversity and representation of the pilot participants, as well as test program response to real life management changes. We suggest that the pilot last for 1-3 years and that pilot farms should receive payments tied to the performance results of their management changes. During this period, it is essential for the pilot program to emphasize regular communication with the pilot farmer participants to understand the impact of the PES on their farm, including challenges and opportunities. The key outcomes of the pilot program are to refine the program structure, further test sensitivity of the models to management changes and assess the experience of farmers in the program.

7.4. Full implementation and measuring success

After knowledge gaps are addressed and the program is refined following the pilot, the Vermont PES would be ready for full implementation. Box 3 below identifies the main stages of implementation through the perspective of a farmer from screening to monitoring to program evaluation.

Box 3. Conceptual process for the PES performance-based contracts with Vermont farmers.



For project administrators, full implementation should be complemented by a continuous process of measurement and verification. Other PES programs have been evaluated using many different metrics. Practice-based programs like ALUS and CRP use the number of farms and number of acres enrolled as indicators of success.[92] For Vermont, estimating the contributions of a Vermont PES towards meeting watershed P loading reduction goals will be the most important indicator of success. Additional metrics of success include the number, type and percent of farms enrolled, the average earnings of farms enrolled and farmer and stakeholder perceptions of program value and impact.

To allow for the continual improvement of ecosystem service measurement metrics and to support the innovation of farmers within the program, we also suggest that the program consider including a separate innovation fund. The innovation fund would enable innovative farmers to try new management strategies that show potential to improve ecosystem service provisioning, but have been untested and potentially not well incorporated into measurement models. We suggest that participation in the

[92] U.S. Department of Agriculture (USDA), "Summary of Summary of Performance and Financial Information for Fiscal Year 2016," 2016; ALUS Canada, "What We Do," accessed June 5, 2019, https://alus.ca/what-we-do/.

innovation fund be considered on a case-by-case basis. Participation would involve participating farmers working closely with program administrators and researchers to develop to new strategies to measure and test ecosystem service impacts of innovative management strategies.

7.5. Verification

It will be important to verify impacts of program enrollment, both in terms of ecosystem services and farm viability. Verification in the California Healthy Soils program uses field visits and soil testing to ensure that farmers are maintaining changes in the PES contract.[93] Verification of agricultural management changes is also achievable by utilizing aerial imagery analysis tools to estimate tillage, cover and crop residue.[94] Our recommendation is annual soil tests and a combination of strategies dependent upon each farm's proposed changes, modeled after the guidelines established by the California Healthy Soils Program.[95] Emphasis on community-based measurement and monitoring would be appropriate in the context because local people have interest and investment in the status of water quality improvement and soil health indicators.[96] Additionally, this approach is in line with measurements and data collection that most farms are already engaged in and are supported by UVM Extension.

[93] California Department of Food and Agriculture (CDFA), "Request for Grant Applications. 2018 Healthy Soils Program Incentives Program," 2018.

[94] RS Bricklemyer et al., "Monitoring and Verifying Agricultural Practices Related to Soil Carbon Sequestration with Satellite Imagery," *Elsevier*, accessed June 11, 2019, https://www.sciencedirect.com/science/article/pii/S016788090600171X; Virginia Gewin, "New Market Planned to Pay Farmers for Soil Carbon, Water," Fern's Ag Insider, 2019, https://thefern.org/ag_insider/new-market-planned-to-pay-farmers-for-soil-carbon-water-quality/.

[95] California Department of Food and Agriculture (CDFA). (2019). 2018 HSP Incentives Program Practices: Payment Rates, Implementation Guidelines and Verification Requirements - Revised Jan 25, 2019. 8 pages

[96] M. K. McCall, N. Chutz, and M. Skutsch, "Moving from Measuring, Reporting, Verification (MRV) of Forest Carbon to Community Mapping, Measuring, Monitoring (MMM): Perspectives from Mexico," ed. Manuel Boissiere, *PLOS ONE* 11, no. 6 (June 14, 2016): e0146038, https://doi.org/10.1371/journal.pone.0146038.

8. CONCLUSIONS

A PES for Vermont is a promising possibility to recognize farmers as stewards of ecosystems and providers of important public benefits. We are confident that if the PES for Vermont is designed in a careful, inclusive and pragmatic way, it can both contribute to improvements in water quality in the state and support the economic viability of Vermont farms.

There is currently a high level of interest in a PES for Vermont. We hope that this white paper may contribute to the on-going conversation about the role of PES for agriculture and water quality in the state. This past legislative session, the Vermont legislature passed an act that creates a Payment for Ecosystem Services Working Group to develop a report on creating a PES to incentivize the adoption of practices, beyond regulatory requirements, to improve water quality and soil health.[97] Ongoing work by the Vermont Dairy and Water Collaborative, the Future of Vermont Agriculture group and collaborations between farmer watersheds groups throughout the state are also continuing to move the conversation forward on a PES for Vermont. We see each of these efforts as making important contributions to the conversation on PES in the state and we hope to see collaboration and coordination across these efforts to bring a diversity of ideas and perspectives to the table.

It is an exciting moment for PES in Vermont and it has been a great experience for us as a class to conduct this study in the midst of this rapidly growing interest by so many groups. We have enjoyed the many opportunities to present our findings to the different groups. Our hope is that the literature and recommendations that we have presented here will contribute meaningfully to the ongoing efforts to design the right PES program for Vermont.

[97] Vermont General Assembly S.160. 2019. An act relating to agricultural development. Retrieved from: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT083/ACT083%20As%20Enacted.pdf