CLIMATE
ACTION
RESERVE

Soil Enrichment Protocol

Reducing emissions and enhancing soil carbon
sequestration on agricultural lands

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Acknowledgements

Reserve staff (alphabetical)

Craig Ebert
Sami Osman
Heather Raven
Jon Remucal
Sarah Wescott

Workgroup

The list of workgroup members below comprises all individuals and organizations who have assisted in developing the protocol. For more information, see section 4.3 of the Reserve Offset Program Manual.

Adam Chambers	USDA Natural Resources Conservation Service
Amrith Gunasekara	California Department of Food and Agriculture
Bill Schleizer	Delta Institute
Christian Davies	Shell
Daniel Kammen	University of California, Berkeley
Dorn Cox	OpenTEAM
Grayson Badgley	Columbia University
Jacqueline Gehrig-Fasel	TREES Consulting LLC
Jonathan Sanderman	Woods Hole Research Center
Justin Allen	Salk Institute
Karen Haugen-Kozyra	Viresco Solutions Inc
Keith Paustian	Colorado State University
Ken Newcombe	C-Quest Capital
Matt Ramlow	World Resources Institute
Max DuBuisson	Indigo Ag, Inc.
Mitchell Hora	Continuum Ag
Nicholas Goeser	Alliance of Crop, Soil and Environmental Science Societies
Patrick Splichal	SES, Inc.
Robert Parkhurst	Sierra View Consulting
Stephen Wood	The Nature Conservancy
Tom Cannon	Goodson Ranch LP
Tom Stoddard	NativeEnergy

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Abbreviations and Acronyms

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CH_4	Methane
CRT	Climate Reserve Tonne
dm	Dry matter
GHG	Greenhouse gas
N_2O	Nitrous oxide
NRCS	USDA Natural Resources Conservation Service
Reserve	Climate Action Reserve
SEP	Soil Enrichment Protocol (this document)
SOC	Soil organic carbon
SSR	Source, sink, and reservoir
t	Metric ton (or tonne)
USDA	U.S. Department of Agriculture

1 Introduction

The Climate Action Reserve (Reserve) Soil Enrichment Protocol (SEP) provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with projects which reduce emissions and enhance soil carbon sequestration on agricultural lands through the adoption of sustainable agricultural land management activities.

The Climate Action Reserve is an environmental nonprofit organization that promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. A pioneer in carbon accounting, the Reserve serves as an approved Offset Project Registry (OPR) for the State of California's Cap-and-Trade Program and plays an integral role in supporting the issuance and administration of compliance offsets. The Reserve also establishes high quality standards for offset projects in the North American voluntary carbon market and operates a transparent, publicly accessible registry for carbon credits generated under its standards.

Project developers that initiate soil enrichment projects use this document to quantify and register GHG reductions with the Reserve. The protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Reserve Verification Program Manual[1] and Section 8 of this protocol.

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with a soil enrichment project.[2]

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[1] Available at http://www.climateactionreserve.org/how/verification/verification-program-manual/.

[2] See the WRI/WBCSD GHG Protocol for Project Accounting (Part I, Chapter 4) for a description of GHG reduction project accounting principles.

2 The GHG Reduction Project

2.1 Background

Agricultural lands have the ability to both emit and sequester carbon dioxide (CO_2), the primary GHG responsible for human-caused climate change (IPCC, 2014). Annual and perennial plants, through the process of photosynthesis, naturally absorb CO_2 from the atmosphere and store the gas as carbon in their biomass (i.e., plant tissues). As plants grow and respire, some of this carbon is deposited in the soil as root exudates. As plants die and regrow, some of this carbon is also deposited in the soil as particulate matter. This carbon cycling occurs throughout the year, with positive and negative fluxes over time depending on soil conditions, climatic conditions, management practices, and other variables.

Depending on how agricultural lands are managed or impacted by natural and human events, they can be a net source of emissions, resulting in a decrease to the reservoir, or a net sink, resulting in an increase of CO_2 to the reservoir. In other words, agricultural lands may have a net negative or net positive impact on the climate, depending on their characteristics and management. Globally, agriculture, forestry, and other land use sectors contribute to 24% of total GHG emissions (IPCC, 2014). Agriculture alone accounts for 9% of all GHG emissions in the U.S. (U.S. EPA, 2020). Through sustainable management and protection, agricultural lands can play a positive and significant role to help address global climate change. This protocol is designed to take advantage of agricultural lands' unique capacity to sequester, store, and emit CO_2 and to facilitate the positive role that these lands can play to address climate change.

In addition, agricultural land management activities are a source of GHG emissions separate from the fluxes of the SOC pool. Activities such as equipment use, fertilizer application, residue management, and livestock grazing management cause emissions of CO_2, CH_4, and N_2O. Changes to these practices can lead to reductions in these emissions, as well as impacts to the flux of CO_2 in the soil.

Soil enrichment activities encompass an enormous variety of practices, with tremendous potential for development of new practices. This approach to farming is intended to restore the health of the soil over time, through continuous and adaptive practice change, rebuilding losses due to conventional agricultural practices. This protocol focuses on outcomes in terms of net GHG flux, and project participants are able to apply the most appropriate practices for their given situation.

2.2 Project Definition

For the purpose of this protocol, the GHG reduction project is defined as the adoption of agricultural management practices that are intended to increase soil organic carbon (SOC) storage and/or decrease net emissions of CO_2, CH_4, and N_2O from agricultural operations, as compared to the baseline. Soil enrichment projects must be located on land which is, as of the project start date, cropland or grassland (including managed rangeland and/or pastureland), and which remains in agricultural production throughout the crediting period. Projects may not include areas which have been cleared of native ecosystems within the 10 years prior to the project start date.

Project activities must not decrease carbon stocks in woody perennials on the project area. Project activities which result in a significant displacement of any pre-existing cash crop production in the project area, or result in displacement of livestock outside the project area must accounted for the risk of emissions leakage according to the procedures in Section 5.5.

2.2.1 Defining the Project Activities

Project activities are those activities that are necessary for the implementation and maintenance of one or more new agricultural land management practices which are reasonably expected (over the project crediting period) to increase SOC storage and/or reduce emissions of CO_2, CH_4, and/or N_2O from agricultural land management activities. SOC storage and GHG emissions in the project scenario are compared against a baseline scenario, which assumes that, in the absence of the project, the baseline land management activities would have been continued.

Land management practices considered for soil enrichment projects are those which result in one or more changes to:

- Fertilizer (organic or inorganic) application; and/or,
- Water management/irrigation; and/or,
- Tillage and/or residue management; and/or,
- Crop planting and harvesting (e.g., crop rotations, cover crops); and/or,
- Fossil fuel usage; and/or,
- Application of synthetic inputs other than fertilizer; and/or,
- Grazing practices and emissions.

Eligibility of project activities is described in more detail in Section 3.4.1. Guidance for assessing and accounting for potential emissions leakage due to soil enrichment project activities is provided in Section 5.5.

2.2.2 Defining the Project Area

For the purposes of this protocol, the project area is defined as an eligible field or fields on which eligible project activities occur. Fields should be configured to exclude areas that do not meet the eligibility requirements set out below (for instance, the field boundary should be drawn to exclude areas containing histosol soils, as those are ineligible). Fields that are split by minor breaks consisting of ineligible areas (i.e., fields split by roads, tree breaks, hedgerows, or watercourses) can still be considered a single field, if desired.

The project area must adhere to the following criteria:

- Each field must be clearly delineated.
- The area within each field must be continuous.
- The same crop (or crop mix) must be grown throughout each field within a reporting period.
- Permanent or improved roads[3], watercourses, and other physical boundaries must be excluded (i.e., such areas will not be included in project area acreage).
- The project area shall not contain any histosols.[4]

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[3] Ephemeral field lands are not required to be excluded, so long as they do not remain in the same location permanently.

[4] Histosols are found at all altitudes, but the vast majority occurs in lowlands. Common names are peat soils, muck soils, and bog soils. See USDA-NRCS, Keys to Soil Taxonomy. Available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/taxonomy/?cid=nrcs142p2_053580.

- The project may contain tile-drained fields, as long as tile-drains were in place during the baseline period (i.e., not installed for the purposes of the project).
- If the project area includes land classified as highly erodible land (HEL),[5] that land must meet federal Highly Erodible Land Conservation provisions to be eligible under this protocol.
- If the project area includes land classified as wetlands,[6] that land must meet federal Wetlands Conservation provisions[7] to be eligible under this protocol.

2.2.3 Project Aggregation

Individual soil enrichment projects may group together multiple fields and/or Field Managers into one larger, aggregated, or grouped, project. An aggregated project shall be considered to be a single "project" everywhere that this document uses that term. Aggregated projects are subject to the following conditions:

- There is no absolute minimum or maximum size for a field or an individual Field Manager's fields to be included in the project
- The entire project must share a common Project Owner, as defined in Section 2.3.1.

2.2.3.1 Entering an Aggregated Project

Individual fields may join a project by being added to the project's Project Submittal form (if joining a project at initiation) or by being added through the Field Enrollment & Transfer form (if joining once the project is underway).

The project developer managing the project that receives the new fields will be responsible for submitting the Field Enrollment & Transfer form, listing the field(s) that are now joining their project, as well as updating a list of enrolled fields contained within the form. Emission reductions occurring on new fields entering a project may start counting toward the project's CRTs in the reporting period during which the field joined the project. Emission reductions will be reported as a single combined project for the reporting period in which the transfer occurred. Any period of time that has already been reported and verified under a single project will not be included in reporting under the newly combined project.

Each field will only be eligible for the duration of its own crediting period, regardless of the point in time at which it joins the aggregated project. All fields in a project must use the same version of this protocol, and if a field from one project joins another project, then the newest version of the protocol in use between them must be adopted for the newly combined project.

Projects that have already been submitted to the Reserve may choose to join another existing project by submitting a Field Enrollment & Transfer form to the Reserve.

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[5] Highly erodible land is defined as "land that has an erodibility index of 8 or more" in Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2. Part 12.21 further outlines how HEL is identified and how the erodibility index is calculated.

[6] Wetlands generally have a predominance of hydric soil and are inundated or saturated by surface or groundwater for various durations over the year. See Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2 for the definition of wetlands. It is also worth noting that wetlands in the project area may also be impacted by the applicability conditions in Section 2.2 of this protocol.

[7] As outlined in Title 7 of the Code of Federal Regulations, Subpart A, Part 12.5(b), and in Section 510.10 of the National Food Security Act Manual. Such exemptions may include wetlands farmed prior to 1985, wetlands with minimal effect, or wetlands with mitigation measures in place.

2.2.3.2 Leaving a Project

Fields must meet the requirements in this section in order to change projects or leave to become their own project and continue reporting emission reductions to the Reserve. In all cases, emission reductions must be attributed to one project for a complete reporting period, as defined in Section 3.3, and no CRTs may be claimed by a project for a field that does not participate and report data for a full reporting period. Reporting for each field must be continuous to remain participating and avoid termination, regardless whether transferring to another existing project or leaving to establish a new project. If a project would like to forgo credits for a period of time in order to delay verification, this is considered a Zero-Credit Reporting Period.[8] Project activities on an individual field may be terminated and the field may be removed from the project at any time, pursuant to the requirements of Section 3.5.

In order for a field or fields to leave a project and join another existing project, the project developer for the receiving project must submit a Field Enrollment & Transfer form to the Reserve, noting that it is a “field transfer” and identifying the project from which it transferred, and the project to which it is being transferred. Reporting under the destination project shall continue according to the guidance in Section 7.

For fields that leave a project to become a separate project, the deadline for submittal of the subsequent monitoring or verification report (whichever is sooner) is extended by 12 months beyond the deadline specified in Section 7.3. The project must submit either a monitoring report or verification report (whichever is due) by this new deadline in order to keep the project active with the Reserve. The project developer setting up the new project will need to submit a Project Submittal form to the Reserve to initiate the new project.

2.3 Project Ownership Structures and Terminology

Soil enrichment projects will generally involve several parties playing different roles. This section outlines key participants and the ownership structures allowed for soil enrichment projects.

Table 2.1. Summary of Project Ownership Categories

Term	Definition	Required Participant?
Landowner	The entity with title to the physical property that contains one or more fields within the project area.	No
Field Manager	The entity with management control over agricultural management activities for one or more fields within the project area.	Yes
Project Developer	An entity which manages the monitoring, reporting, and verification, including interaction with the online registry.	Yes
Project Owner	The entity with legal ownership of the GHG reduction rights for the entire project area.	Yes
Aggregator	A Project Owner whose project contains multiple Field Managers.	No

In the table above, any of the other defined entities could be the Project Owner. In an aggregated project, one of the Field Managers could be the Project Owner and the aggregator, or those roles may be filled by a third party. In any case, the project developer may be a contracted third-party (i.e., a technical consultant).

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[8] See the Reserve Program Manual, available at: http://www.climateactionreserve.org/how/program/program-manual/.

2.3.1 The Landowner and the Field Manager

The term “landowner” is not given special meaning for this protocol beyond the commonly understood meaning of the word. There is no requirement for direct participation of the landowner or for production of land title documentation. For the purposes of this protocol, the term “Field Manager” is defined in Section 2.3. Every project will involve at least one Field Manager. A soil enrichment project is defined in relation to management of a specific area of land, and thus the project activities are attributed to the Field Manager for that field. Unless there exists a legal instrument transferring the ownership rights to the GHG emission reductions to an entity other than the Field Manager, the Field Manager is assumed to be the Project Owner for the relevant field(s). Field Managers may, however, transfer ownership of the GHG reduction rights to a third party.

2.3.2 The Project Owner

Every project will have a single Project Owner. CRTs will only be issued to the Reserve account of the Project Owner, and, as such, the Project Owner must maintain an active account on the Reserve in order to receive such issuance(s). The Project Owner must have clear ownership of the project’s GHG reductions during the period covered by the Project Implementation Agreement (Section 3.5.3). The Project Owner may be the Field Manager or a third-party entity who has a signed contract with the Field Manager conveying title to the GHG reduction rights related to the relevant field(s). In the case of third-party ownership, the ownership of the GHG reductions must be established by clear and explicit contracts. The Project Owner must attest to such ownership by signing the Reserve’s Attestation of Title form.[9] The Project Owner shall execute the Project Implementation Agreement (PIA). The Project Owner is also responsible for the accuracy and completeness of all information submitted to the Reserve, and for ensuring compliance with this protocol, even if the Project Owner contracts with an outside entity to carry out these activities (e.g., a technical consultant).

Sample language related to ownership of emission reductions is included below, to be amended to fit each project’s specific situation:

> *“TITLE TO CARBON OFFSET CREDITS. The [grantor/grantee - i.e., whichever party to the agreement is the Project Owner] hereby retains, owns, and holds legal title to and all beneficial ownership rights to the following (the “Project Reductions”): (i) any removal, limitation, reduction, avoidance, sequestration, or mitigation of any greenhouse gas associated with the Property including without limitation Climate Action Reserve Project No. [___] and (ii) any right, interest, credit, entitlement, benefit, or allowance to emit (present or future) arising from or associated with any of the foregoing, including without limitation the exclusive right to be issued carbon offset credits or Climate Reserve Tonnes (CRTs) by a third party entity such as the Climate Action Reserve.”*

In all cases, the Project Owner must attest to the Reserve that they have exclusive claim to the GHG reductions resulting from the project, by signing the Attestation of Title described above. Each time a project is verified, the Project Owner must attest that no other entities are reporting or claiming (e.g., for voluntary reporting or regulatory compliance purposes) the GHG reductions caused by the project. The Reserve will not issue CRTs for GHG reductions or sequestration that is reported or claimed by entities other than the Project Owner (e.g., the landowner for a field where the Field Manager is a lessee). Attestations must be signed by the Project Owner.

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[9] Attestation of Title form available at http://www.climateactionreserve.org/how/program/documents/.

Project Owners are ultimately responsible for timely submittal of all required forms and complying with the terms of this protocol. Project Owners may designate a technical consultant to manage the flow of documents and information to the Reserve. The scope of services provided by a technical consultant should be determined by the Project Owner and the relevant management entity and reflected in the contracts between the Project Owner and the relevant management entity.

2.4 Non-GHG Impacts of Project Activities

The Soil Enrichment Protocol (this document) is intended to reduce emissions and enhance soil carbon sequestration on agricultural lands, through the adoption of sustainable agricultural land management activities. Natural working lands that are managed for agricultural purposes, regardless of location or management, are subject to forces that could degrade ecosystem services such as water quality, biodiversity, and degrading soil organic carbon and microbiome diversity. The Reserve requires project developers to demonstrate that their GHG projects will not undermine progress on other environmental issues such as air and water quality, endangered species and natural resource protection, and environmental justice.

Whilst the sustainable agricultural land management practices eligible and encouraged under this protocol are expected to achieve beneficial GHG impacts on the project area (see Section 2.1), the project developer should nonetheless take care and all reasonable precautions to ensure no broader harms are caused by the project. Since eligible practices should constitute an overall improvement relative to historical management, it is unlikely that the project activity will result in significant negative non-GHG impacts. When registering a project, the project developer must attest that the project was in material compliance with all applicable laws, including environmental regulations, during the verification period. The project developer is also required to disclose any and all instances of non-compliance – material or otherwise – of the project with any law to the Reserve and the verification body. Section 3.6 contains guidance with respect to ensuring the project meets these regulatory compliance requirements.

Although not an explicit requirement of this protocol, the Reserve also encourages project developers to report on the potential environmental co-benefits of their projects, such as reductions in other air pollutants, improvements in water quality, enhancement of wildlife habitat, etc. One example of co-benefits the Reserve would like to recognize is the significant contributions made by farmers who have already begun to implement such sustainable agricultural practices. The pioneering work done by farmers in adopting such practices has and will continue to be instrumental in demonstrating to other farmers what is possible and profitable. Whilst it is not always possible for offset protocols to recognize such critical early action, via crediting for the associated emission reduction impacts, due to additionality concerns, it would be entirely appropriate for project developers to voluntarily recognize such early action as part of their optional accounting of the co-benefits associated with their projects. It should be noted that the Reserve has been approved as an official provider of offsets for the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to voluntarily abate emissions from international aviation. In order to be eligible to supply offsets to CORSIA, each project must report on co-benefits, in accordance with guidance enshrined in the latest version of the Reserve Offset Program Manual.[10]

The Reserve does not seek to prescribe specific land management activities. Rather, the intent of this section is to encourage thoughtful and proactive land management to maintain and/or

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[10] A copy of the latest version of the Reserve Offset Program Manual can be downloaded from the Reserve website here: http://www.climateactionreserve.org/how/program/program-manual/.

improve ecosystem services. In order to protect against potential negative impacts, project developers should identify potential negative environmental and socio-economic impacts and identify the steps that have been, or will be, taken to mitigate and/or monitor them.

3 Eligibility Rules

Projects that meet the definition of a GHG reduction project in Section 2.2 must fully satisfy the following eligibility rules in order to register with the Reserve.

Section 3.1	Location	→	*U.S. and its tribal lands and territories*
Section 3.2	Project Start Date	→	*No more than 24 months prior to project submission*
Section 3.3	Project Crediting Period	→	*Emission reductions may only be credited during the crediting period*
Section 3.4	Additionality	→ →	*Meet performance standard* *Exceed regulatory requirements*
Section 3.5	Permanence	→	*One hundred years following the issuance of CRTs, or employing tonne-year accounting or an alternative mechanism for ensuring permanence*
Section 3.6	Regulatory Compliance	→	*Compliance with all applicable laws*

3.1 Location

Only projects located in the United States, U.S. territories, and on U.S. tribal lands are eligible to register with the Reserve. See Section 2.2.3 for guidance on what constituted eligible project areas.

If drainage tile is employed on the project area, it must have been installed prior to the historic baseline period, and undrained fields may not have tile installed during the project scenario.

3.2 Project Start Date

The project start date is defined as the first day of the cultivation cycle during which the eligible practice change was adopted. For aggregated projects, the start date is set in relation to each individual field. See Section 7.2 for details regarding defining the cultivation cycle.

Projects with start dates on or after [*June 10, 2018*] are eligible. The project must be submitted to the Reserve no more than 24 months after the later of either the project start date or the date of adoption of this protocol.[11] Projects may always be submitted for listing by the Reserve prior to their start date. For projects that are transferring to the Reserve from other offset registries, start date guidance can be found in the Reserve Offset Program Manual.

3.3 Project Crediting Period

The crediting period for projects under this protocol is 30 years. For aggregated projects, the crediting period is assessed at the individual field level, meaning each field may only be credited for up to 30 years, but the overall project may earn credits for greater than 30 years. Projects, or

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[11] Projects are considered submitted when the project developer has fully completed and filed the appropriate Project Submittal form, available at http://www.climateactionreserve.org/how/program/documents/.

individual fields, may choose to end their crediting period earlier than 30 years, subject to the requirements for permanence (Section 3.5). The crediting period for this protocol is not renewable.

However, the Reserve will cease to issue CRTs for any given eligible practice(s) if at any point in the future, the practice(s) become legally required, as defined by the terms of the legal requirement test (see Section 3.4.2). Thus, the Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of 30 years for each given field after the project start date, or until the project activity is required by law. Where an eligible practice becomes mandated by law, fields are still eligible to receive credits for other practices, so long as the baseline is updated to reflect the now-mandatory practice going forward.

The project crediting period begins at the project start date regardless of whether sufficient monitoring data are available to verify GHG reductions.

3.4 Additionality

The Reserve strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy the following tests to be considered additional:

1. The performance standard test
2. The legal requirement test

3.4.1 The Performance Standard Test

Projects pass the performance standard test by meeting a performance threshold, i.e., a standard of performance applicable to all soil enrichment projects, established by this protocol.

The performance standard test is applied at the time when a project applies for registration with the Reserve. Additionality for a soil enrichment project is demonstrated by the adoption, during the growing season which defines the project start date, of one or more changes in pre-existing agricultural management practices that are reasonably expected (over the project crediting period) to increase SOC storage and/or reduce emissions of CO_2, CH_4, and/or N_2O from agricultural land management activities. Adoption is defined as a change from a baseline management scenario to a project management scenario, and may involve either implementation of a new activity (e.g., introducing cover crops), cessation of a pre-existing activity (e.g., tillage), significant adjustment of a pre-existing activity (e.g., reduced N application rate), or some combination. A change in practice includes adoption of a new practice (e.g., adoption of one of the illustrative soil enrichment practices listed in Appendix B), cessation of a pre-existing practice (e.g., stop tillage or irrigation) or adjustment to a pre-existing practice (e.g., reduction in N application rate). Field Managers may also choose to implement multiple practice changes, either at the project initiation, or, more likely, over time as they become successful with the initial change(s). In any case, the change adopted by the Field Manager must be expected to either increase SOC storage or decrease GHG emissions on the project area. Adoption of a new practice change during the project lifetime does not alter the crediting period for a field.

Practice changes may be qualitative (e.g., adding a cover crop into the crop rotation) or quantitative (e.g., reducing the nitrogen fertilizer application rate). In any case, to be eligible for a soil enrichment project, the change must be of a type and magnitude which is able to be quantified using the modeling approach selected for the reporting period, and. In any case, the magnitude of the practice change must be such that a reasonable person, knowing the context of the baseline scenario in the relevant region, would consider it to be a new management practice. Additional information regarding the performance standard test can be found in Appendix A.

3.4.1.1 Defining the Baseline Scenario

The baseline scenario assumes the continuation of pre-project agricultural management practices. For each sample unit (e.g., field), practices applied in the baseline scenario are determined by defining an historical baseline period to produce a baseline schedule of activities. The length of the historical period shall be no less than three years, and shall at least be long enough to encompass a complete rotation of crops and management practices (e.g., if the same crop is grown every year, but the field is only tilled every three years, the historical period must be at least three years). If the baseline rotation extends beyond five years, it is not required to extend the period beyond five years. Projects may always extend the historical period farther back in time, if desired. Additionally, at least three years of management practice data are needed for each crop grown in the baseline period.

The historical period has two distinct purposes, which helps to determine how many years of data are necessary for a given field:

1. For biogeochemical process-based models, the historical period is used to “spin-up” the model to determine the appropriate inputs for the modeling of the baseline and project scenarios in the first cultivation cycle of the project. This purpose may not be relevant for use of empirical models.

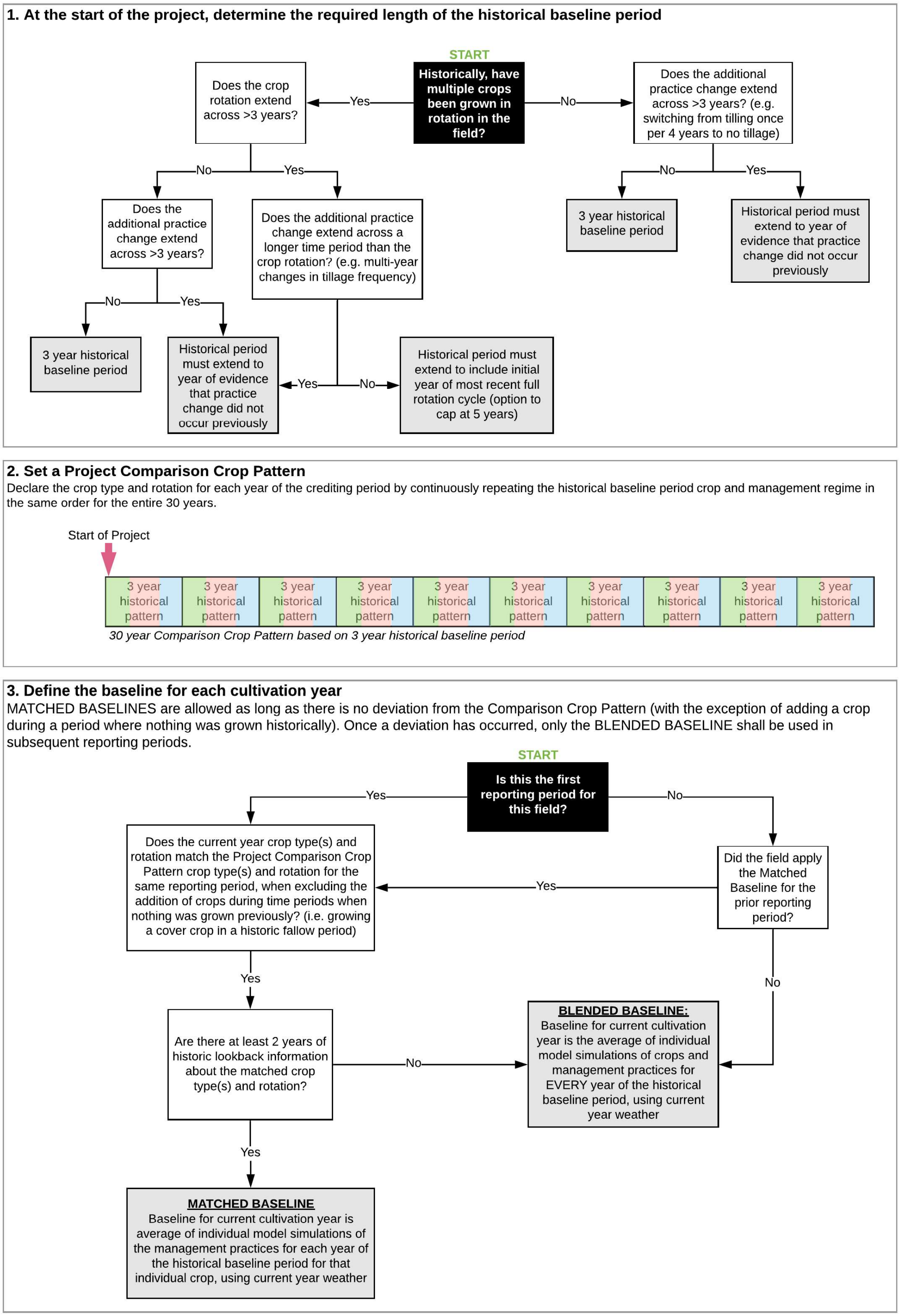
2. For every project the historical data are used in order to model the baseline changes in pools and sources for which the project is employing the use of models. In this case, the selection of which years of data are to be simulated and averaged together to determine the baseline are set according to the guidance below.

For each cultivation cycle of the crediting period, the project developer must define the counterfactual baseline scenario in a way that most appropriately compares the project scenario against what would have happened in the absence of the project activities. This can become complicated depending on whether the project activities involve changes to the baseline rotation of crop and management activities. Figure 3.1 provides guidance for determining the appropriate baseline for various change cases. This protocol allows for two different baseline modeling approaches, with only one of the two being appropriate depending on whether the activities on the reporting period match those in the historical baseline period:

1. **Matched Baseline**
   This is the default baseline approach, and must be applied for as long as the project continues the same crop rotation as existed in the historical baseline period. A matched baseline means that in the current project year, the model will be used to individually simulate at least two cultivation cycles from the historical baseline period which were growing the same crop as the current project year. These simulations are done using the weather from the current project year, and the outputs from the model are averaged together to determine the baseline SOC stock change and emissions.

2. **Blended Baseline**

If the matched approach cannot be employed, because the reporting period crop rotation or individual choice of crop no longer matches the historical baseline rotation of crops, then this blended approach must be used. The only exception to this simple rule is that the matched approach can be used if in the reporting period a crop is grown whereas in baseline rotation there would have been a fallow year. A blended baseline means that in the current reporting period, the model will be used to individually simulate every year from the historical baseline period, regardless of crop. These simulations are done using the weather from the current project year, and the outputs from the model are averaged together to determine the baseline SOC stock change and emissions.



1. At the start of the project, determine the required length of the historical baseline period

2. Set a Project Comparison Crop Pattern

Declare the crop type and rotation for each year of the crediting period by continuously repeating the historical baseline period crop and management regime in the same order for the entire 30 years.

30 year Comparison Crop Pattern based on 3 year historical baseline period

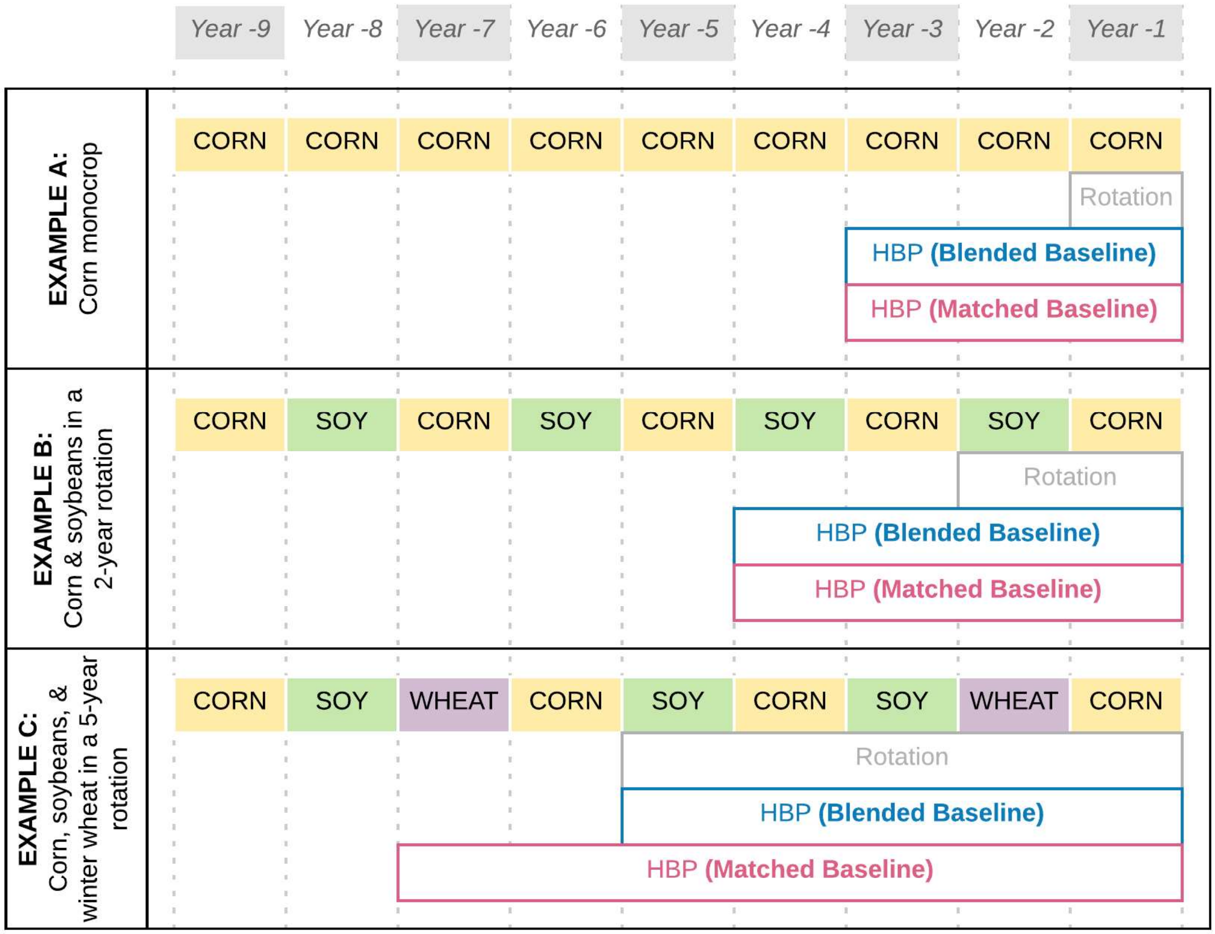
3. Define the baseline for each cultivation year

MATCHED BASELINES are allowed as long as there is no deviation from the Comparison Crop Pattern (with the exception of adding a crop during a period where nothing was grown historically). Once a deviation has occurred, only the BLENDED BASELINE shall be used in subsequent reporting periods.

Figure 3.1. Baseline Setting Process and Decision Tree

Invariably, the minimum length of the historical baseline period will also be determined by data requirements for the biogeochemical model chosen to model baseline emissions (see Section 5.1 for guidance on baseline quantification). A longer historical baseline period is always preferable and encouraged, even if it encompasses multiple rotations of similar management practices, as this will enhance the ability of the baseline modeling to account for the long-term trends due to baseline practices.

Figure 3.2, below, illustrates several potential baseline crop rotation scenarios. For each scenario, A, B, and C, the figure notes the full length of the most recent rotation, as well as the number of years of historical data needed to complete the baseline modeling for each crop in the project scenario. These examples assume that the projects using the blended baseline approach need only go back far enough to capture the full crop rotation, although this may need to be more than one rotation if the crop rotation is less than three years. Example A shows how a field with a monocropping system would capture three “rotations” to satisfy the minimum requirement for three years. Example B shows how a field with a two-year rotation would have a historical baseline period of four years, satisfying both the three-year minimum, as well as the need to capture complete rotations. Example C shows that a field with a five-year crop rotation would only need to consider one full rotation for the blended baseline approach, but for the matched baseline approach would need to capture one additional year of data related to growing wheat.



HBP = Historical Baseline Period

Figure 3.2. Examples for Defining the Historical Crop Rotation and Baseline Period

3.4.1.2 Data Collection for Activities in the Baseline Scenario

For each sample unit, a schedule of activities in the baseline scenario will be determined by assessment of practices implemented during the *x* crop years prior to the project start date (with *x* indicating at least one complete rotation of crops and management practices, defined as above). For each year, $t = -1$ to $t = -x$, the following required information on agricultural management practices (where applicable) will be determined (Table 3.1). These minimum data requirements encompass critical and sensitive inputs into biogeochemical models and may require model-specific adjustments when used to quantify baselines. For example, plant and harvest dates may be input on a specific day, or may be input within a specific month, depending on whether the model runs on a daily or a monthly timestep. Animal stocking rates offer another example, which may be input directly in some models, while others may need a conversion to grazing intensity on plant biomass. The schedule of baseline activities and the conversion of qualitative and quantitative data described in Table 3.1 into model inputs should be clearly described and will be discussed in more detail in Section 5.1.

Table 3.1. Minimum Data Parameters for Development of the Baseline Scenario

Agricultural Management Practice	Qualitative Data	Quantitative Data
Crop	▪ Crop type(s)	▪ Approximate date(s) planted (if applicable) ▪ Approximate date(s) harvested / terminated (if applicable)
Soil amendments	▪ Manure (Y/N) ▪ Compost (Y/N) ▪ Synthetic N fertilizer (Y/N) ▪ Crop residue removal approach: o Minimal residue removal, e.g., grain only harvest o Partial residue removal, e.g., baled straw o Maximum residue harvest, e.g., silage	▪ Manure application rate (if applicable) ▪ Compost application rate (if applicable) ▪ Synthetic N fertilizer application rate (if applicable)
Irrigation or other hydrological management	▪ Irrigation (Y/N) ▪ Flooding (Y/N)	▪ Irrigation rate (if applicable)
Tillage	▪ Tillage (Y/N)	▪ Depth of tillage (if applicable)
Grazing	▪ Grazing (Y/N)	▪ Animal type (if applicable) ▪ Animal stocking rate (if applicable)

Qualitative information on agricultural management practices will be determined via consultation with, and substantiated with a signed attestation from, the Field Manager of the sample field during the reporting period.

The source of quantitative information on agricultural management practices, and any additional quantitative inputs where required by the model selected or by the equations in Section 5, shall be chosen with priority from higher to lower preference, as available, as follows:

1. Historical management records supported by one or more forms of documented evidence pertaining to the selected sample field and period $t = -1$ to $t = -x$ (e.g., management logs, receipts or invoices, farm equipment specifications, logs or files containing machine and/or sensor data), or remote sensing (e.g., satellite imagery, manned aerial vehicle footage, drone imagery), where requisite information on agricultural management practices can be reliably determined with these methods (e.g., tillage status, crop type, irrigation).

2. Historical management plans supported by one or more forms of documented evidence pertaining to the selected sample field and period $t = -1$ to $t = -x$ (e.g., management plan, recommendations in writing solicited by the farmer or landowner from an agronomist). Where more than one value is documented in historical management plans (e.g., where a range of application rates are prescribed in written recommendations), the principle of conservatism will be applied, selecting the value that results in the lowest expected emissions (or highest rate of stock change) in the baseline scenario.

3. Determined as a reporting period average value for that input, for the given project. Any reporting period average for any given crop and cultivation cycle must include at least 30

fields within the same Land Resource Region (LRR) which were growing the same crop in the same calendar year.

4. Determined via consultation with, and substantiated with a signed attestation from, the Field Manager of the sample field during that period - so long as the attested value does not deviate significantly from other evidence-supported values for similar fields (e.g., fertilizer data from adjacent fields with the same crop, adjacent years of the same field, government data of application rates in that area, or statement from a local extension agent regarding local application rates).
5. Regional (sub-national) average values derived from agricultural census data or other sources from within the 10-year period preceding the project start date, referencing the relevant crop or ownership class where estimates have been disaggregated by those attributes. Examples include the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Quick Stats database[12] and USDA Agricultural Resource Management Survey (ARMS).[13]

3.4.2 The Legal Requirement Test

All projects are subject to a legal requirement test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to federal, state, or local regulations, or other legally binding mandates.

To satisfy the legal requirement test, Project Owners must submit a signed Attestation of Voluntary Implementation form[14] prior to the commencement of verification activities each time the project is verified (see Section 8). In addition, the project's Monitoring Plan (Section 6) must include procedures that the Project Owner will follow to ascertain and demonstrate that the project at all times passes the legal requirement test.

3.4.3 Ecosystem Services Payment Stacking

When multiple ecosystem services credits or payments are sought for a single activity on a single piece of land, with some temporal overlap between the different credits or payments, it is referred to as "credit stacking" or "payment stacking," respectively (Cooley & Olander, 2011). Under this protocol, credit stacking is defined as receiving both offset credits and other types of mitigation credits for the same activity on spatially overlapping areas (i.e., in the same acre). Mitigation credits are any instruments issued for the purpose of offsetting the environmental impacts of another entity, such as emissions of GHGs, removal of wetlands or discharge of pollutants into waterways, to name a few. Payment stacking is defined as issuing mitigation credits for a best management or conservation practice that is also funded by the government or other parties via grants, subsidies, payment, etc., on the same land.

Generally speaking, the Reserve does not prohibit either payment or credit stacking, under this protocol, unless such payments or credits are specifically delineated per tCO_2e. Guidance and approval must be sought from the Reserve regarding any possible stacking of payments or credits with soil enrichment projects. Guidance should also be sought from the complementary program that is to be stacked with the SEP, to ensure such overlap is not prohibited by the other complementary program. Any type of conservation or ecosystem service payment or credit

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[12] https://quickstats.nass.usda.gov.

[13] https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Ag_Resource_Management/index2.php.

[14] Attestation forms are available at http://www.climateactionreserve.org/how/program/documents/.

received for activities on the project area must be disclosed by the Project Owner to the verification body and the Reserve on an ongoing basis.

3.4.3.1 Credit Stacking

The Reserve did not identify any active mitigation credit market opportunities which would impact soil enrichment projects. Potential opportunities exist, however, which should be monitored over time and assessed as they mature and become available for overlap with soil enrichment projects. These potential opportunities include carbon sequestration tax credits, water quality trading programs, water quantity trading programs, and non-GHG impact certifications.

3.4.3.2 Payment Stacking

The Reserve has identified two general types of payments that support the project activities being credited under this protocol: "landscape-scale" payments and "enhancement" payments. The majority of these payments are available via programs implemented by the USDA NRCS. NRCS expressly allows the sale of environmental credits from enrolled lands,[15] but it does not provide any further guidance on ensuring the additional environmental benefit of any payment for ecosystem service stacked with an NRCS payment.

Landscape-Scale Payments

Landscape-scale payments generally come from land conservation programs that prevent grazing and pastureland from being converted into cropland, used for urban development, or developed for other non-grazing uses. Participants in these programs voluntarily limit future development of their land through the use of long-term contracts or easements, and payments are generally made based on the value of the land being protected.

Given that soil enrichment projects are crediting based on changes to land management practices, rather than avoided conversion, these landscape-scale payment programs do not pose a concern.

Because every available landscape-scale payment is not comprehensively addressed by the protocol at this time, the Project Owner must disclose any such payments to the verifier and the Reserve on an ongoing basis. The Reserve maintains the right to determine if payment stacking has occurred and whether it would impact project eligibility.

Enhancement Payments

Enhancement payments provide financial assistance to landowners in order to implement discrete conservation practices that address natural resource concerns and deliver environmental benefits. For government-funded enhancement payments, participants sign short-term contracts and receive annual cost-share payments specific to the conservation practice they have implemented. Examples of relevant enhancement payments include:

- NRCS Environmental Quality Incentives Program (2014 Farm Bill)
- NRCS Conservation Stewardship Program (2014 Farm Bill)
- NRCS Continuous Conservation Reserve Program (2008 Farm Bill)
- NRCS Wildlife Habitat Incentive Program (2008 Farm Bill)

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[15] Environmental Quality Incentives Program: 7 CFR §1466.36; CSP, 7 CFR §1470.37.

The practices that are compensated for by the programs above are based on minimum, standardized definitions, and do not require monitoring and reporting on GHG benefits. Payments are tied to activity, but not performance. Because of this, Field Managers may pursue enhancement payments without restriction. Because every available enhancement payment is not comprehensively addressed by the protocol at this time, the Project Owner must still disclose any such payments to the verifier and the Reserve on an ongoing basis.

3.5 Requirements for Permanence

The Reserve requires that credited reversible GHG reductions and removals be effectively “permanent” in order to serve as valid offset credits. For the purposes of this protocol, a reversible emission reduction is considered “permanent” if the quantity of carbon associated with that reduction is stored for at least 100 years following the issuance of a credit for that reduction or issued credits proportional to the 100-year permanence timeframe, as described in Section 3.5.6. For example, if CRTs are issued to a soil enrichment project in year 24 following its start date, soil carbon in the project area must be maintained for 100 years, through at least year 124. An emission reduction is considered reversible if it is related to carbon which remains stored in a carbon pool, such as soil organic carbon, but could be released back into the atmosphere under certain conditions. An example of a nonreversible emission reduction on a soil enrichment project would be the avoided N_2O emissions related to baseline fertilizer use. Furthermore, once an emission reduction is considered permanent, it is no longer considered reversible.

To meet this requirement, Project Owners must put in place sufficient mechanisms to effectively monitor and report on the status of a soil enrichment project for a minimum period of 100 years following the issuance of any CRT for GHG reductions achieved by the project, unless the project is terminated or the project opts to be issued credits based on a tonne-year accounting basis (see Section 3.5.6). Unless the Reserve approves the use of an alternative mechanism to maintain permanence, failure to maintain ongoing monitoring and reporting may result in the automatic termination of the project. Note that this means that monitoring and reporting for a project may be required to continue even after the end of the project’s crediting period. The period of time after the project crediting period has ended and before the minimum time commitment has been met is referred to as the “permanence period” (see Section 3.5.4).

The Reserve ensures the permanence of GHG reductions and removals through five mechanisms:

1. The requirement for all Project Owners to monitor for potential reversals of soil organic carbon, submit regular monitoring reports, and submit to regular third-party verification of those reports (as detailed in Sections 6 through 8 of this protocol) for the duration of the crediting period and permanence period, unless an alternative mechanism is approved.
2. The requirement—in order to receive more than the one-tonne-year equivalent value of emission reductions in each year—for all Project Owners to sign a Project Implementation Agreement with the Reserve, described below in Section 3.5.3, which obligates Project Owners to supply CRTs to compensate for reversals of GHG reductions and removals for a set period of time.
3. The maintenance of a Buffer Pool to provide insurance against reversals of GHG reductions and removals due to unavoidable causes (see Sections 3.5.2 and 5.3.1).
4. Alternative mechanisms for ensuring the permanence of crediting GHG reductions and removals (see Section 3.5.5).

5. The optional application of tonne-year accounting, in combination with or in lieu of the other permanence mechanisms (see Section 3.5.6).

3.5.1 Defining Reversals

If carbon is released before the end of the 100-year period after a CRT is issued, the release is termed a “reversal”. A reversal occurs if stored carbon is actually released through a disturbance of the project area or is deemed to be released through termination of the project or a portion of the project. Reversals may impact only a portion of the project area or the entire project area. Regardless of the area of impact had by a reversal, permanence will be assessed at the project level, rather than the individual field level. Decreases of SOC on individual fields will not affect permanence, so long as the project as a whole has had a stable or increasing SOC pool over the relevant time period.

This protocol distinguishes between two categories of reversals, avoidable and unavoidable, and specifies separate remedies for each. Many biological and non-biological agents, both natural and human-induced, can cause reversals. Some of these agents cannot completely be controlled (and are therefore “unavoidable”), such as natural agents like fire or flooding. This protocol also takes into consideration the extent to which a Project Owner has contributed towards the reversal through negligence, gross negligence, or willful intent. Thus, reversals caused by biological agents, where the Project Owner has not contributed to the reversal through negligence, gross negligence, or willful intent, are considered unavoidable. These unavoidable reversals are compensated for by the Buffer Pool, as described in Section 5.3.2.2.

An avoidable reversal occurs if:

1. The Project Owner voluntarily terminates the project prior to the end of the 100-year time commitment. A Project Owner may voluntarily terminate the entire project, or a portion of the project area. If only a portion is terminated, then the reversal is considered to affect only the terminated area.
2. There is a breach of certain terms described within the Project Implementation Agreement (see Section 3.5.3, below). Such a breach results in the entire project being automatically terminated.
3. The Project Owner prematurely ceases ongoing monitoring and verification activities. Monitoring, reporting, and verification requirements are described in Sections 6, 7, and 8. Cessation of required monitoring and verification results in the entire project being automatically terminated.
4. Any activity occurs on the project area that leads to a significant disruption of soil carbon. Examples include, but are not limited to, sustained increase in tillage, eminent domain, or mining or drilling activities. In most cases, such disturbances would not constitute a reversal on the entire project area.
5. A natural disturbance occurs to the soil carbon in the project area, and the Reserve determines that the disturbance is attributable to the Field Managers’ or Project Owner’s negligence, gross negligence, or intentional mismanagement of the project area as agricultural land.

Avoidable reversals must be communicated to the Reserve and compensated for by the Project Owner, as prescribed in Section 5.3.2.1

3.5.2 About the Buffer Pool

The Buffer Pool is a holding account for CRTs from sequestration-based projects, which is administered by the Reserve. All soil enrichment projects must contribute a percentage of CRTs to the Buffer Pool any time they are issued CRTs for verified GHG reductions and removals. Each project's contribution is determined by a project-specific risk rating, as described in Section 5.3.1. If a project experiences an unavoidable reversal of GHG reductions and removals (as defined in Section 5.3.2), the Reserve will retire a number of CRTs from the Buffer Pool equal to the total amount of carbon that was reversed (measured in metric tons of CO_2e). The Buffer Pool therefore acts as a general insurance mechanism against unavoidable reversals for all soil enrichment registered with the Reserve. Management and disposition of the Buffer Pool is described in the Reserve Offset Program Manual.

3.5.3 Project Implementation Agreement

Permanence obligations are guaranteed through a legal agreement that obligates the Project Owner to conduct monitoring activities on the project area for a defined period, and to compensate for avoidable reversals that occur during the permanence commitment, typically the 100-year period following CRT issuance (unless a project employs tonne-year accounting or receives approval for a shorter commitment through other safeguards). For soil enrichment projects, this agreement is known as the Project Implementation Agreement. Requirements for monitoring and reporting activities during the permanence period are detailed in Section 7.3.

The PIA is an agreement between the Reserve and a Project Owner setting forth: (i) the Project Owner's obligation (and the obligation of its successors and assigns) to comply with the Soil Enrichment Protocol, and (ii) the rights and remedies of the Reserve in the event of any failure of the Project Owner to comply with its obligations. The PIA must be signed by the Project Owner before a project can be registered with the Reserve. The PIA is a contract between the Project Owner and Reserve, whereby the Project Owner agrees to the requirements of the protocol, including but not limited to monitoring, verification, and compensating for reversals. The risk of financial failure of the Project Owner, and therefore the Reserve's ability to act on the terms of the PIA, is factored into the project's Buffer Pool contribution, as described in Section 5.3.1.

The PIA does not restrict the transferability of the specific CRTs issued, but does hold the Project Owner to the compensation requirements of Section 5.3.2. By the terms of the PIA, the contract is satisfied upon the Project Owner's full performance of the requirements of this protocol. The PIA is executed and submitted after the Reserve has reviewed the verification documents and is otherwise ready to register the project. It is not possible to terminate the PIA for only a portion of the project area; however, an amended PIA may be executed that reflects a change to the project area as provided for by the exceptions to the minimum time commitment at the beginning of this section. The PIA is also amended at each subsequent verification in order to extend the term of applicability. The PIA for soil enrichment projects is not a public document.

The length of the PIA may be selected by the Project Owner at the time of its execution. However, if the term of enforcement of the PIA is less than 100 years following CRT issuance, then one of the following must occur to avoid the finding of a complete reversal at the end of the contract term:

1. The PIA is extended, with the Project Owner accepting further obligations for monitoring and reporting for reversals;

2. The Project Owner receives written approval from the Reserve for an alternative mechanism for ensuring permanence on the project area (see Section 3.5.3); or,
3. The Project Owner elects to be issued credits based on tonne-year accounting (see Section 3.5.6), with credit issuance based on the tonne-year values associated with the length of the term of enforcement of the PIA.

3.5.4 Permanence Period

When the crediting period for a field has concluded, the field enters a "permanence period" until the minimum time commitment is met. During this time, the field must continue to be monitored to demonstrate that a reversal has not occurred. This may be accomplished remotely and must follow the requirements in Section 6.1. If monitoring requirements are not met, the Reserve will consider this to be an avoidable reversal, which must be compensated for by the Project Owner.

With the exception of Project Owners that choose to use the tonne-year accounting approach, if a field opts out of the program prior to the end of its crediting period, the Project Owner must choose one of two options:

1. They can consider CRTs issued based on GHG removals from the field to be automatically reversed. Depending on the number of fields exiting the program, this may not cause a reversal for the project, since reversal compensation is assessed at the project level; or
2. The field automatically enters the permanence period monitoring procedures.
    a. If the grower has been shown to have maintained their adopted practice(s) for 5 years following the opt-out, then permanence monitoring may conclude. As described in Appendix A, growers are generally reluctant to change their land management practices for a variety of reasons. If they have maintained their adopted practice(s) without payment following opting out of the project, we can consider that they will continue to maintain that practice (or practices), and the SOC can be considered effectively permanent.

3.5.5 Alternative Mechanisms for Ensuring Permanence

The "standard" approach to satisfying the requirements of the permanence period is for the Project Owner to maintain active monitoring and reporting on the presence or absence of the reversals, under the obligations of a PIA that covers the full 100 years following CRT issuance. However, this protocol allows for soil enrichment projects to implement alternative mechanisms for ensuring permanence which would allow for reversals to be identified and compensated without ongoing participation or legal obligation for the Project Owner.

Alternative mechanisms for ensuring permanence must:

1. Be approved in writing by the Reserve prior to the expiration of the PIA; and,
2. Provide either a reasonable mechanism for ongoing monitoring of the project area or evidence that the risk of avoidable reversal can be reasonably considered to be de minimis in relation to the reversible emission reductions already issued; and,
3. Where risk of reversal still exists, put in place a mechanism to compensate for any reversal which is identified.

The following are examples of possible alternative mechanisms for ensuring permanence. None of these examples constitute pre-approval of the methodology – a proposal would still need to be submitted to the Reserve for review and approval:

1. An example of a reasonable mechanism for ongoing monitoring would be an automated system for assessment of the project area through remote sensing which is programmed to identify reversals through an accepted list of proxy events. Such a system would need to be accessible to Reserve staff, able to generate notifications for the Project Owner (to be reported to the Reserve), and able to measure the areal extent of any reversal identified.
2. An example of a mechanism to determine that the risk of avoidable reversal is de minimis would be demonstration of growers' long-term adoption of project practices above a certain threshold. For example, if a certain high percentage of Field Managers maintain their SEP practices consistently throughout the crediting period and for at least 5 years following the conclusion of the crediting period, then permanence monitoring may conclude. This assertion of maintenance of practices must be verified and approved by the Reserve.
3. An example of a mechanism to compensate for reversals in the absence of an obligation under the PIA would be a financial product, such as direct insurance or surety bonds. The use of such alternative financial mechanisms during the crediting period reduces the required buffer pool contribution related to the risk of financial failure, as described in Section 5.3.1. The Reserve must review and approve alternative financial mechanisms before they may be used.

3.5.6 Tonne-Year Accounting

Additional reductions of atmospheric CO_2 are realized immediately when CO_2 is sequestered in a carbon pool at levels beyond "business as usual." However, the additional sequestered CO_2 completely mitigates an equal GHG emission elsewhere only when that additional sequestered CO_2 is maintained out of the atmosphere for at least 100 years. In the event a Project Owner does not commit to the storage of reversible carbon stocks for 100 years or employ one of the alternative permanence mechanisms outlined in Section 3.5.5, permanence of the emissions reductions will be achieved by the application of tonne-year accounting (TYA).

Whereas tonne-tonne accounting (TTA) recognizes the entire climate benefit of a permanently sequestered tonne of CO_2 by issuing one credit for each tonne of CO_2 sequestered and maintained for 100 years, tonne-year accounting (TYA) recognizes the time-value of CO_2 held out of the atmosphere for time periods less than the full commitment period of 100 years. Thus, even if additional sequestered CO_2 is maintained for less than 100 years, credits can be issued as a proportion of the 100-year permanence timeframe achieved. Under this protocol, credits are recognized under TYA at a rate of 1 percent per tonne of CO_2e per year. Projects electing to employ the TYA option do not need to meet the 100-year commitment described in the preceding sections, but will be issued fewer credits, based on the length of the commitment. After their commitment period ends, these projects will not be required to maintain ongoing monitoring for reversals.

Crediting for reversible emission reductions will be based on the remaining length of the permanence commitment compared to the vintage year of the credits. For example, if a project executes a PIA with a term of 20 years, credits for reversible emission reductions will be issued on the following schedule in Table 3.2 (assuming the permanence commitment is never renewed or extended).

Table 3.2. Schedule for Issuance of Reversible Emission Reduction Credits

Project Year	Percentage of Current Year Emission Reductions to be Issued upon Successful Verification = 21% – MIN(Project Year, 20)%
1	20%
2	19%
3 - 20	18% - 1%[16]
21	1%
22 - 30	1%

This schedule may be altered by amending the existing PIA or executing a new PIA. See Equation 5.2.B for guidance on determining the appropriate basis for credit issuance for a given reporting period based on the length of the commitment under the PIA. Requirements for reversals are only applicable within the commitment period.

3.6 Regulatory Compliance

As a final eligibility requirement, project developers must attest that project activities do not cause material violations of applicable laws (e.g., air, water quality, safety, etc.). To satisfy this requirement, Project Owners must submit a signed Attestation of Regulatory Compliance form[17] prior to the commencement of verification activities each time the project is verified. Project Owners are also required to disclose in writing to the verifier any and all instances of legal violations – material or otherwise – caused by the project activities, or that are in any way related to the project fields. Verifiers are in turn required to disclose any such violations in writing to the Reserve. In order to avoid delays in crediting, all such violations should be reported to the Reserve at the earliest possible time.

The Reserve will determine that a violation is to be considered to have been “caused” by project activities if it can be reasonably argued that the violation would not have occurred in the absence of the project activities. If the Reserve finds that project activities have caused a material violation, then CRTs will not be issued for GHG reductions that occurred during the period(s) when the violation occurred. Individual violations due to administrative or reporting issues, or due to “acts of nature,” are not considered material and will not affect CRT crediting. However, recurrent administrative violations directly related to project activities may affect crediting. The Reserve will determine if recurrent violations rise to the level of materiality. If the verifier is unable to assess the materiality of the violation, then the verifier shall consult with the Reserve.

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[16] Each subsequent year after year 3 receives 1% less than the previous year. For example, on year 4 the issuance is 17% of total emission reductions, on year 5 it is 16%, and so on. This reflects that the contractual commitment established on year one is diminishing over time and with that the proportion of emission reductions that can be issued up front.

[17] Attestation forms are available at http://www.climateactionreserve.org/how/program/documents/.

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that must be assessed by project developers in order to determine the net change in emissions caused by a soil enrichment project.

Figure 4.1 illustrates all relevant GHG SSRs associated with soil enrichment project activities and delineates the GHG Assessment Boundary.

Table 4.1 provides greater detail on each SSR and justification for the inclusion or exclusion of certain SSRs and gases from the GHG Assessment Boundary.

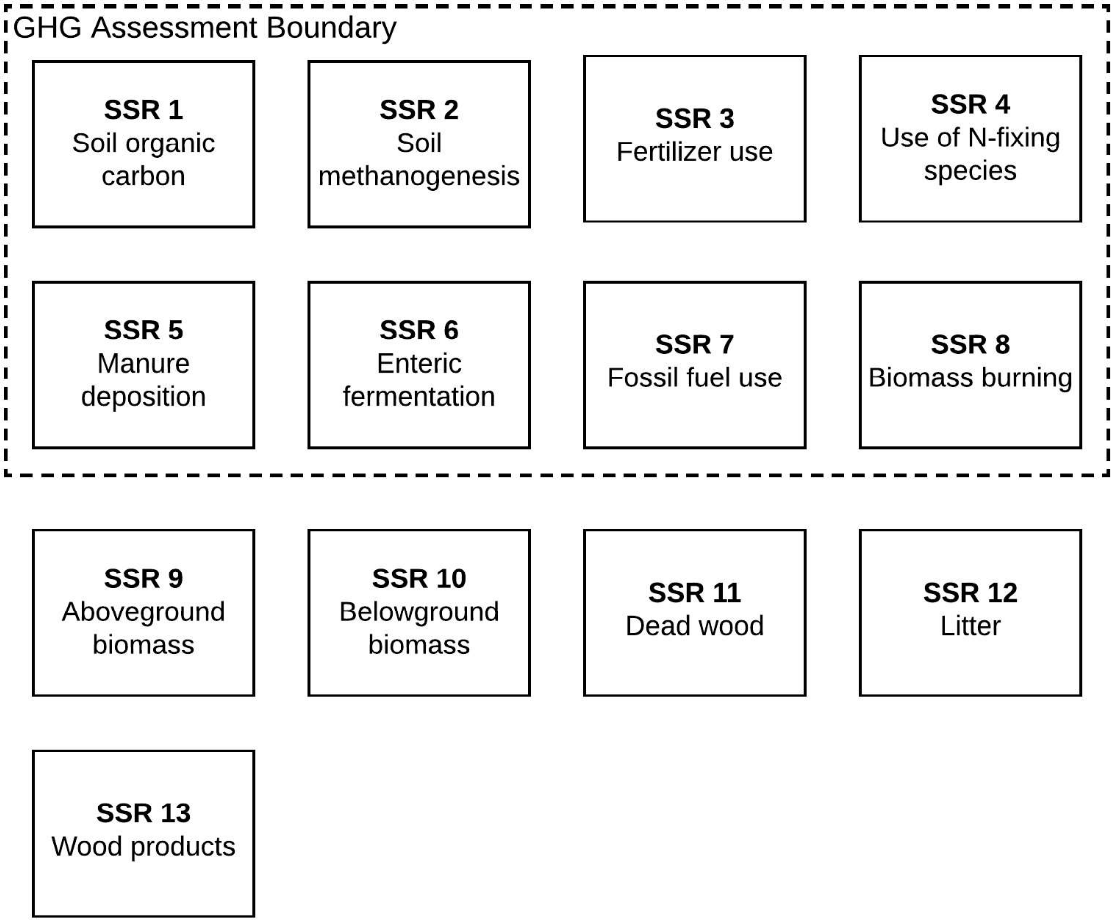

Figure 4.1. General Illustration of the GHG Assessment Boundary
All SSRs are relevant in both the baseline and project scenarios.

Table 4.1. Description of all Sources, Sinks, and Reservoirs

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Baseline (B) or Project (P)	Justification/Explanation
1	Soil organic carbon	C	I	Modeled and measured	B,P	Major carbon pool affected by the project activity that is expected to increase in the project scenario.
2	Soil methanogenesis	CH_4	I	Modeled	B,P	Must be included where the project activity may significantly increase emissions compared to the baseline and may be included where the project activity may reduce emissions compared to the baseline.
3	Fertilizer use	N_2O	I	Modeled or calculated	B,P	If synthetic and/or organic nitrogen fertilizers are applied in the project or baseline scenarios, N_2O emissions from nitrogen fertilizers must be included in the project boundary.
4	Use of nitrogen fixing species	N_2O	I	Modeled	B,P	If nitrogen fixing species are planted in the project or baseline scenario, N_2O emissions from nitrogen fixing species must be included in the project boundary.
5	Manure deposition	CH_4	I	Modeled or calculated	B,P	If livestock grazing occurs in the project or baseline scenario, CH_4 and N_2O emissions from manure shall be included in the project boundary. Included emissions are those from manure applied to the land directly by livestock or applied to the land from storage, but not those from manure in storage.
		N_2O				
6	Enteric fermentation	CH_4	I	Modeled or calculated	B,P	If livestock grazing occurs in the project or baseline scenario, CH_4 emissions from enteric fermentation shall be included in the project boundary.

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Baseline (B) or Project (P)	Justification/Explanation
7	Fossil fuel use	CO_2	I	Calculated	B,P	Fossil fuel emissions from vehicles and equipment may increase or decrease in the project scenario, depending on practice changes.
8	Biomass burning	CH_4	I	Modeled or calculated	B,P	Must be included where the project activity may significantly increase emissions compared to the baseline and may be included where the project activity may reduce emissions compared to the baseline.
		N_2O				
9	Aboveground biomass	C	E	N/A	N/A	This pool is not expected to experience significant changes in the project scenario.
10	Belowground biomass	C	E	N/A	N/A	Conservatively excluded, as project activities are likely to increase C stocks in this pool.
11	Dead wood	C	E	N/A	N/A	This pool is not expected to experience significant changes in the project scenario.
12	Litter	C	E	N/A	N/A	This pool is not expected to experience significant changes in the project scenario.
13	Wood products	C	E	N/A	N/A	This pool is not expected to experience significant changes in the project scenario.

5 Quantifying GHG Emission Reductions

GHG emission reductions from a soil enrichment project are quantified by comparing modeled and calculated project emissions to the modeled and calculated baseline emissions. Baseline emissions are an estimate of the difference between the soil organic carbon pool in the current reporting period and baseline scenario, as well as the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary. Project emissions must be subtracted from the baseline emissions to quantify the project's net GHG emission reductions for each individual source and gas. The net GHG emission reductions are then summed separately for reversible and non-reversible sources. The length of time over which GHG emission reductions are periodically quantified and reported is called the "reporting period." GHG emission reductions must be quantified and verified for each reporting period (see Section 7.2). In certain cases, a single reporting period may contain more than one cultivation cycle. Project developers may choose to quantify and verify GHG emission reductions on a more frequent basis if they desire.

Table 5.1. Global Warming Potentials for Non-CO_2 Greenhouse Gases

Greenhouse Gas	100-year Global Warming Potential[18]
CH_4	25
N_2O	298

The protocol provides a flexible approach to quantifying emission reductions and removals resulting from the adoption of new agricultural management practices in the project compared to the baseline. Baseline and project emissions are defined in terms of flux of CH_4, and N_2O and net flux of CO_2 in units of metric tons CO_2e per unit area per reporting period. Approaches to quantification of contributing sources for CO_2, CH_4, and N_2O are listed in Table 5.2. Where more than one quantification approach is identified for a given source/pool, projects have the choice of approach, so long as the same approach is used in the baseline and project scenarios.

Soil organic carbon levels must be directly measured in relation to the initiation of the project, as well as at least every five years thereafter. Using this directly measured SOC input, projects must model their baseline SOC stock change (as well as, optionally, CH_4, and N_2O emissions) during each cultivation cycle of the crediting period. Baseline emissions will be remodeled each year using climate data from the project cultivation cycle, following the guidance in Section 5.1. With respect to reporting period (or 'project scenario') emissions, the SOC component must be "trued-up" at least every 5 years using direct measurements. For projects using models to estimate project scenario SOC stocks, the subsequent direct SOC measurement would be used in the same manner as in the first year of the project, as the input to the model simulation for that year. The output SOC stock from that simulation would then be compared to the output SOC stock from the simulation of the prior cultivation cycle to determine the SOC stock change, and thereby incorporating the adjustment for the direct measurement. All other sources, sinks, and reservoirs (SSRs, see Section 4 for guidance on SSRs) can be quantified each year using

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[18] As of this writing, the Reserve relies on values for global warming potential (GWP) of non-CO_2 GHGs published in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007). The values relevant for this protocol are provided in Table 5.1, below. These values are to be used for all soil enrichment projects unless and until the Reserve issues written guidance to the contrary. IPCC 4AR is available here: https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml.

either default equations and emission factors or modeling (as detailed in Table 5.2). In all other intervening years where direct measurement of SOC is not employed, the SOC component can also optionally be quantified using a modeling approach. In reporting periods where direct measurement is employed, if the direct measurement reveals SOC levels for a given field below the previously modeled project scenario SOC for that field, that field will contribute a negative stock change to the overall project quantification for that reporting period. In this way, the measurement method will provide for a reconciliation or ‘true-up’ between the modeled and measured approaches. If the net SOC stock change across the entire project area for a reporting period is found to be negative, this would result in a reversal.

Project Owners must have a Monitoring Plan identifying how direct measurements and modeling are employed in relation to the fulfillment of all project quantification, monitoring, and reporting requirements, as outlined in Section 6.

Table 5.2. Acceptable Quantification Approaches by Source and Gas

GHG	Source	**Modeled** (external to protocol equations)	Directly Measured	Calculated
CO_2	Soil organic carbon	**X**	**X**	
	Fossil fuel use			**X**
CH_4	Methanogenesis	**X**		
	Enteric fermentation	**X**		**X**
	Manure deposition	**X**		**X**
	Biomass burning			**X**
N_2O	Nitrification/denitrification	**X**		**X**
	Manure deposition	**X**		**X**
	Biomass burning			**X**

A typical project will conduct soil sampling in relation to the project initiation (possibly using a model to adjust the SOC measurements backward to the project start date). Those SOC measurements will then form the basis of both the baseline and project scenario modeling for the first cultivation cycle. As shown in Table 5.2, the model may be used only for SOC stocks, or it may also be used to simulate CH_4 and N_2O emissions from methanogenesis, enteric fermentation, manure deposition, and nitrification/denitrification. The project developer may choose instead to use project data to quantify those sources of CH4 and N2O using the equations in this protocol and their relevant default emission factors. However, the same approach must be used in both the baseline and project scenarios and must be consistent across an entire project for a given reporting period.

For example, if a project elected to use modeling to the fullest extent possible, the first two years would employ the activities in Table 5.3. The baseline scenario always pairs historical data with current weather, while the project scenario always pairs current project data with current weather.

Table 5.3. Example Quantification Approach with Maximal Use of Modeling

	Starting SOC	SOC Change	CH_4 (except burning)	CH_4 (burning only)	N_2O (except burning)	N_2O (burning only)	CO_2 from fossil fuels
Year 1 Baseline	Measured	Modeled	Modeled	Default equations	Modeled	Default equations	Default equations
Year 1 Project	Measured	Modeled	Modeled	Default equations	Modeled	Default equations	Default equations
Year 2 Baseline	Modeled	Modeled	Modeled	Default equations	Modeled	Default equations	Default equations
Year 3 Project	Modeled	Modeled	Modeled	Default equations	Modeled	Default equations	Default equations

Figure 5.1, below, illustrates the basic inputs and quantification approaches for the first five years of a project which elects to use modeling to the maximum extent allowed by this protocol.

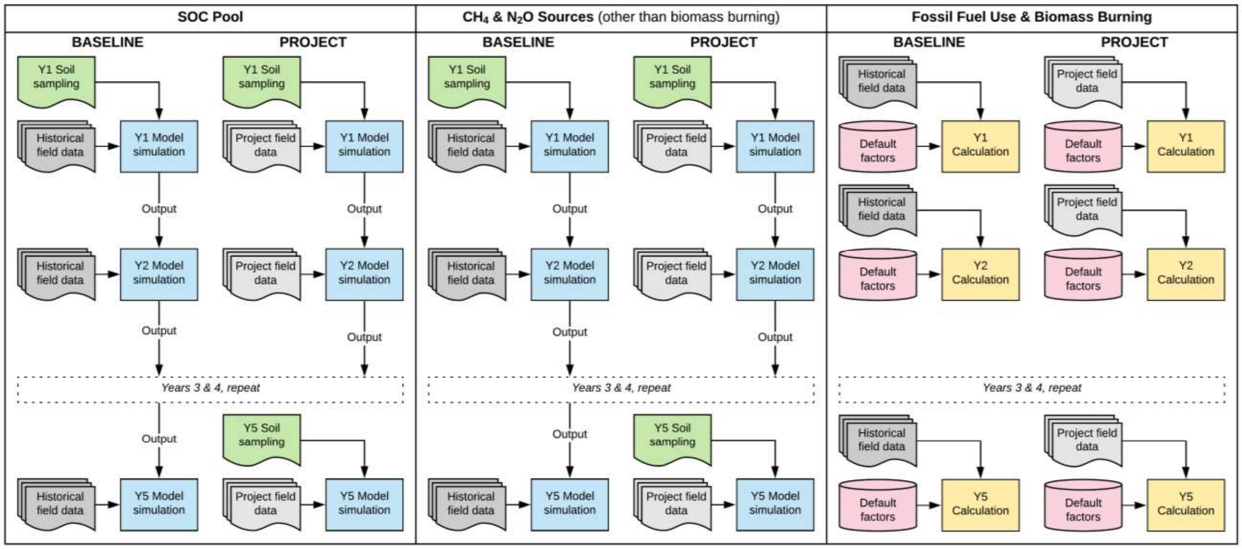

Figure 5.1. Example Data and Process Flow with Maximal Use of Modeling

Alternatively, if a project elected to use modeling to the *least* extent possible, the first two years would employ the activities in Table 5.4. The baseline scenario always pairs historical data with current weather, while the project scenario always pairs current project data with current weather.

Table 5.4. Example Quantification Approach with Minimal Use of Modeling

	Starting SOC	SOC Change	CH_4 (except methanogenesis)	N_2O	CO_2 from fossil fuels
Year 1 Baseline	Measured	Modeled	Default equations	Default equations	Default equations
Year 1 Project	Measured	Modeled	Default equations	Default equations	Default equations
Year 2 Baseline	Modeled	Modeled	Default equations	Default equations	Default equations
Year 3 Project	Modeled	Modeled	Default equations	Default equations	Default equations

Figure 5.2, below, illustrates the basic inputs and quantification approaches for the first five years of a project which elects to use modeling to the least extent possible under this protocol. For situations where a project uses a different combination of models and default equations, the basic information displayed in these examples remains the same.

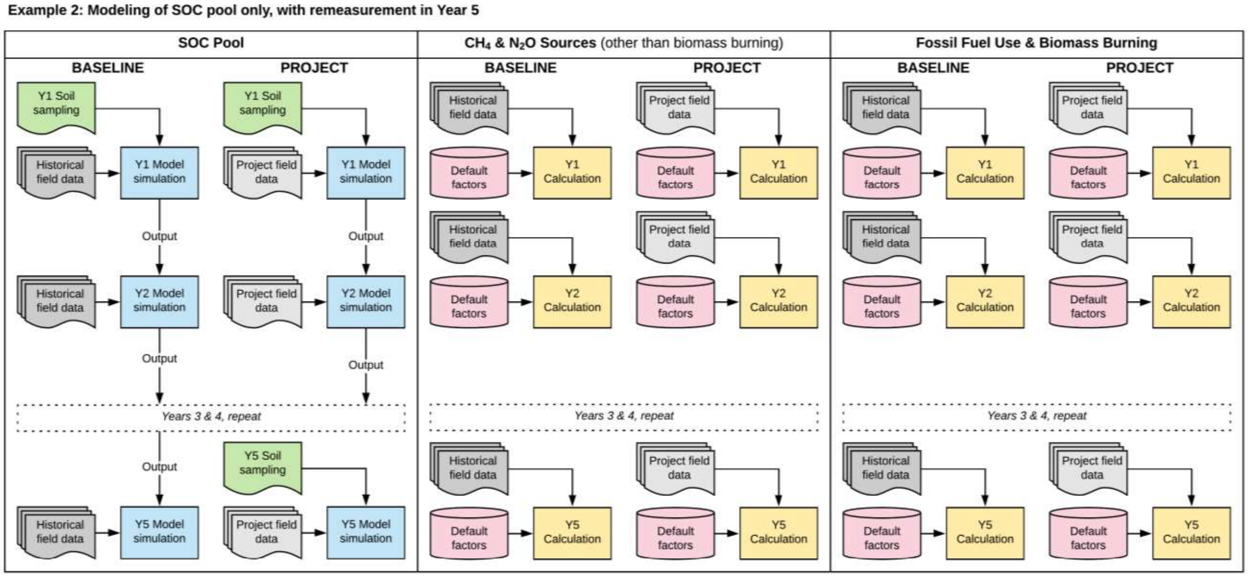

Figure 5.2. Example Data and Process Flow with Maximal Use of Modeling

Figure 5.3 provides a general view of the equations used to quantify soil enrichment projects. As described above, this protocol allows flexibility for quantification of certain gases and pools. The SOC pool must always be either directly measured or modeled. Other sources may be either modeled or calculated using Tier 2 equations in this protocol, as described below. This illustrates the top-level concepts, while the sections below contain more detailed maps of equations.

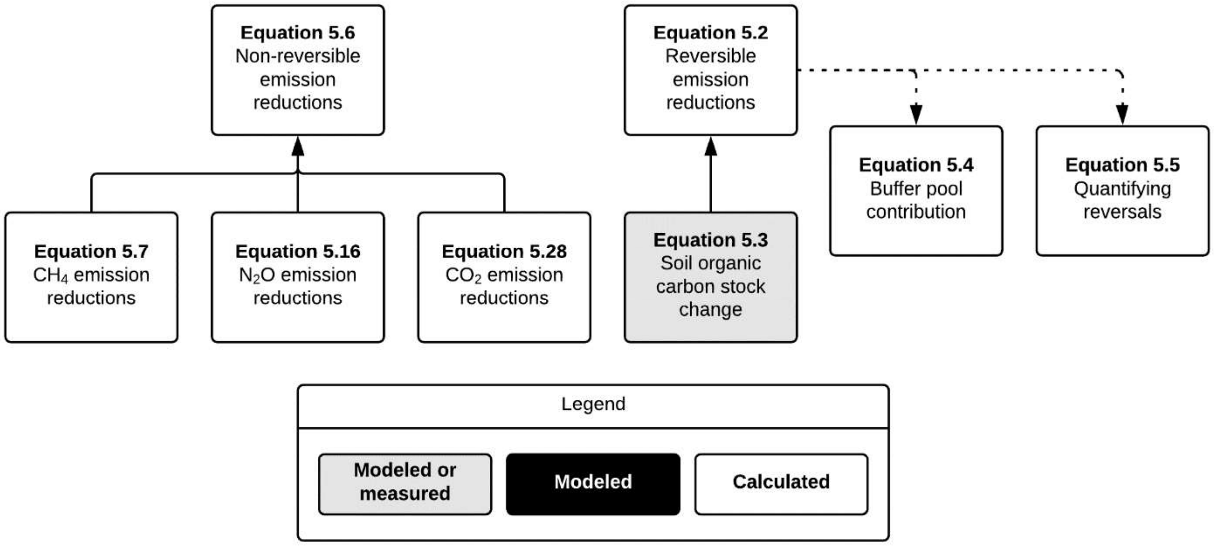

Figure 5.3. Map of Equations to Quantify SEP Projects

The quantification approach in this protocol is designed to accommodate different statistical sampling approaches for the use of directly measured soil data. The project monitoring plan shall provide the definition of “sample unit” as it pertains to the project (e.g., sample point, pixel, field, farm, etc.). The definition of “sample unit” should also address the use of stratification. Stratification should consider such components as crop type, rotation, climate, soil, topography, geography, and management practices. Where the sample unit is contained with a field, but certain data (e.g., practices, weather) are collected for the entire field, those data may be applied to all units within the relevant field. For quantification using direct measurement or modeling, results for each sample unit within a stratum will be averaged together and then applied to the total area of the stratum.

This protocol distinguishes between emission reductions which are reversible (i.e., related to carbon stored in the soil organic carbon pool) and those which are non-reversible (i.e., related to avoided emissions from cultivation activities). Reversible emission reductions are quantified according to Equation 5.2. The permanence requirements of Sections 3.5 and 5.3 apply only to the reversible emission reductions. The non-reversible emission reductions are quantified according to Section 5.4, and are considered permanent at the time of issuance.

Projects will conduct soil sampling and, thus, quantification based on a sub-set of the total project area, known as a sample. Section 6.4 discusses the sample design. In order to apply the results of the quantification of sample units across the entire project area requires the use of averages. The average emission reductions for a sample unit is multiplied by the number of acres in that sample unit. This conceptual approach to using averages in the quantification is described in Box 5.1.

Box 5.1. Target Parameter: Average Emission Reductions of All Gases and Pools

Our target parameter is the total emissions reduction of all gases and pools across the project during the reporting period. To estimate this quantity, we subdivide the area of interest into a set of spatial units of equal area (such as pixels of land), and we denote the reduction in emissions of gas or pool $\boldsymbol{G}$ during time period t at spatial unit i as

$$\Delta G_{t,i} \equiv G_{\mathrm{bsl},t,i} - G_{\mathrm{wp},t,i}$$

where the operator Δ takes the difference between the baseline ("bsl") and project ("pr") emissions to the atmosphere of gas or pool G. The units of $\Delta G_{t,i}$ are tons CO$_2$e per acre per year.

The goal is to estimate the average of $\Delta G_{t,i}$ across all spatial units i, denoted by $\overline{\Delta G_t}$, and then to sum those averages across all gases:

$$\overline{ER_t} = \sum_{\text{gases } G} \overline{\Delta G_t}$$

We estimate these averages using measurements and model simulations on a random subset of the spatial units i. Those estimates are denoted by $\widehat{\overline{\Delta G_t}}$ and $\widehat{\overline{ER_t}}$, and details on those estimates and the associated uncertainty are in Appendix D.

At the final step, the estimated average emissions reduction $\widehat{\overline{ER_t}}$ is multiplied by the area and duration of the reporting period to arrive at an estimate of emissions reduction in tons of CO$_2$e.

5.1 Modeling the Baseline

For soil enrichment projects, the baseline shall be modeled for each cultivation cycle of the crediting period based upon the baseline approach defined in Section 3.4.1.1. For each sample field, a schedule of activities in the baseline scenario will be determined by assessment of practices implemented during the historical baseline period. The interval over which practices are assessed, *x* cultivation cycles, should conform to the specifications described in Section 3.4.1.1.

The baseline SOC and GHG emissions levels shall then be determined by employing the selected biogeochemical model to create simulations that combine historical management practices with project weather, and consider current year crop type for the project following the guidelines described in Section 3.4.1.1. This approach aims to capture the sensitivity of soil processes to actual project weather conditions and crop-specific management. For each cultivation cycle of the project, following minimum data guidelines described in Section 3.4.1.1, historical practices for each crop will be modeled with the selected biogeochemical model, driving the simulation of historical years of practices with weather for that year (i.e., the same weather data should be used to model the baseline as well as the additional practice). The baseline final value for the project year will then be calculated as the average of model predictions across historical baseline schedules of management for that year's baseline crop.

For the SOC pool baseline in project year 1, assuming the project is growing corn in both the baseline and project scenarios (i.e., following the matched baseline approach), the calculation is as follows in Table 5.5.

Table 5.5. Example Baseline SOC Modeling for Initial Reporting Period

Year 1	Input SOC	Weather	Crop & Management	Result
Model run 1.1	Initial	Year 1	Corn Year -1	Sim_{-1}
Model run 1.2	Initial	Year 1	Corn Year -2	Sim_{-2}
BASELINE YEAR 1				**Average(Sim_{-1}, Sim_{-2})**

For the SOC pool project value in project year 1, the calculation is as follows in Table 5.6.

Table 5.6. Example Initial Reporting Period SOC Modeling

Year 1	Input SOC	Weather	Crop & Management	Result
Model run 1	Initial	Year 1	Year 1	Sim_1
PROJECT YEAR 1				**Sim_1**

In each year, the SOC stock change is calculated as the difference between the project result and the baseline result for that year. If SOC is directly measured in that year, then the directly-measured value will represent the input to that year's modeling (unless the project is *only* quantifying project scenario SOC stock changes through direct measurement).

For modeling the baseline in a subsequent year, the averaged baseline results from the prior year are used as the input SOC value, as shown below.

For the SOC pool baseline in project year 2, assuming that the project introduces a third crop into what was previously a two-year corn-soybean rotation, per the guidance in Figure 3.1 (i.e., a blended baseline approach), the calculation is as follows in Table 5.7.

Table 5.7. Example Baseline SOC Modeling for Subsequent Reporting Periods

Year 2	Input SOC	Weather	Crop & Management	Result
Model run 2.1	Y1 baseline	Year 2	Corn Year -1	Sim_{-1}
Model run 2.2	Y1 baseline	Year 2	Corn Year -2	Sim_{-2}
Model run 2.3	Y1 baseline	Year 2	Soybean Year -1	Sim_{-3}
Model run 2.4	Y1 baseline	Year 2	Soybean Year -2	Sim_{-4}
BASELINE YEAR 2				**Average(Sim_{-1}, Sim_{-2}, Sim_{-3}, Sim_{-4})**

For modeling of CH_4 and N_2O, the approach is exactly the same. For projects employing biogeochemical models, the SOC value is used as a model input exactly as laid out in the tables above. For projects using the default factor-based equations in this protocol to quantify the baseline, the SOC stock is not a relevant input. In those cases, however, the approach is the same: the equations are run once for each cultivation cycle in the historic baseline period, with the results averaged together, according to either the matched baseline approach or the blended baseline approach, as applicable.

For the CH_4 and N_2O baseline in project year 1 (assuming the matched baseline approach), the calculation is as follows in Table 5.8.

Table 5.8. Example Initial Reporting Period CH_4 and N_2O Modeling

Year 1	Input SOC	Weather	Crop & Management	Result
Model run 1.1	Initial	Year 1	Corn Year -1	Sim_{-1}
Model run 1.2	Initial	Year 1	Corn Year -2	Sim_{-2}
Model run 1.3	Initial	Year 1	Corn Year -3	Sim_{-3}
BASELINE YEAR 1				**Average(Sim_{-1}, Sim_{-2}, Sim_{-3})**

Figure 5.4 provides an example of the matched baseline approach for a SOC baseline across two project period years, using 5 years of historical information across the complete 5-year crop rotation, and 3 years each of historical information per each crop simulated in the project period. For each project year, all three years of historic practice for the relevant crop are simulated using weather from the project year. The average is then calculated to determine the baseline for that year. The final average value for baseline SOC for that year is then used to repeat the same process for year 2, using the baseline assumptions appropriate to that year's crop, as detailed in Table 3.1. The same approach shall be employed for the baseline emissions of N_2O and CH_4, for sources where modeling is allowed by this protocol (see Table 5.2).

As indicated below, rather than modeling the baseline for a project once at the beginning of the project (or upon entry of each field within an aggregate), baseline modeling is conducted throughout the duration of the project's crediting period(s). For each reporting period, the baseline is modeled for that reporting period only and not for future reporting periods. Thus, a project comprising one field is expected to undertake 30 separate baseline modeling exercises (one for each reporting period for that reporting period), while a project comprising multiple fields should expect to undertake 30 separate baseline modeling exercises for each sample field.

For fields that are employing the Matched Baseline modeling approach, Figure 5.4 illustrates the selection of historical data for the first two cultivation cycles.

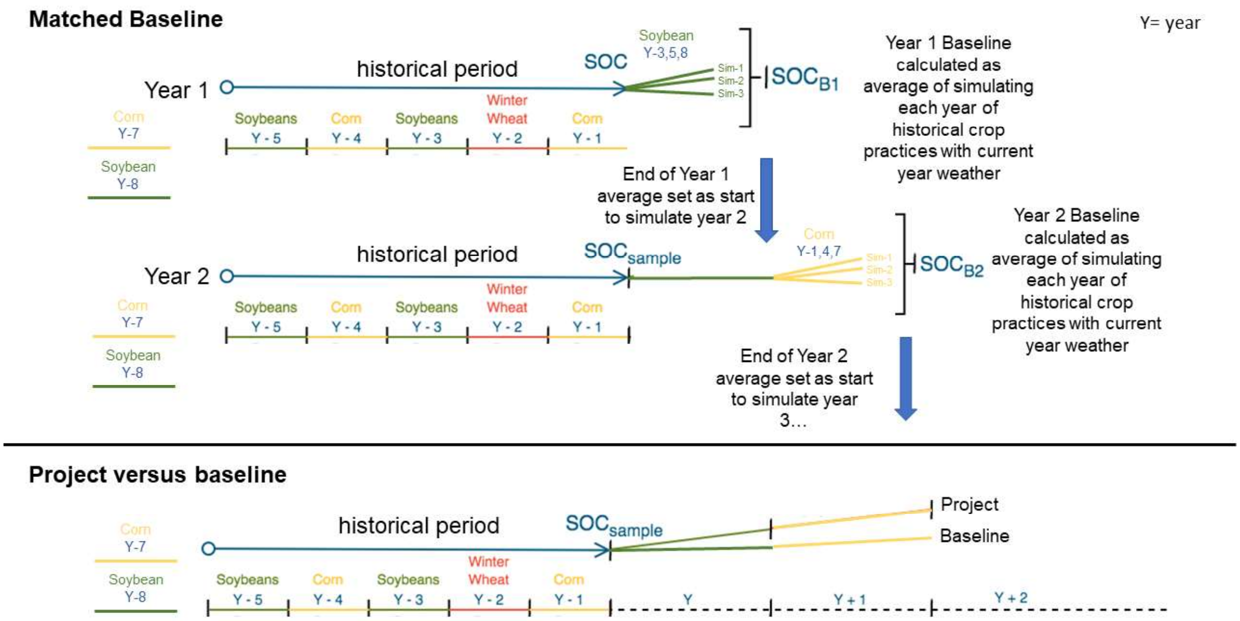

Figure 5.4. Example Diagram for the Matched Baseline Modeling Approach for First 2 Cultivation Cycles of a Crediting Period

For fields that are employing the Blended Baseline modeling approach, Figure 5.5 illustrates the selection of historical data and approach to modeling for the first two cultivation cycles.

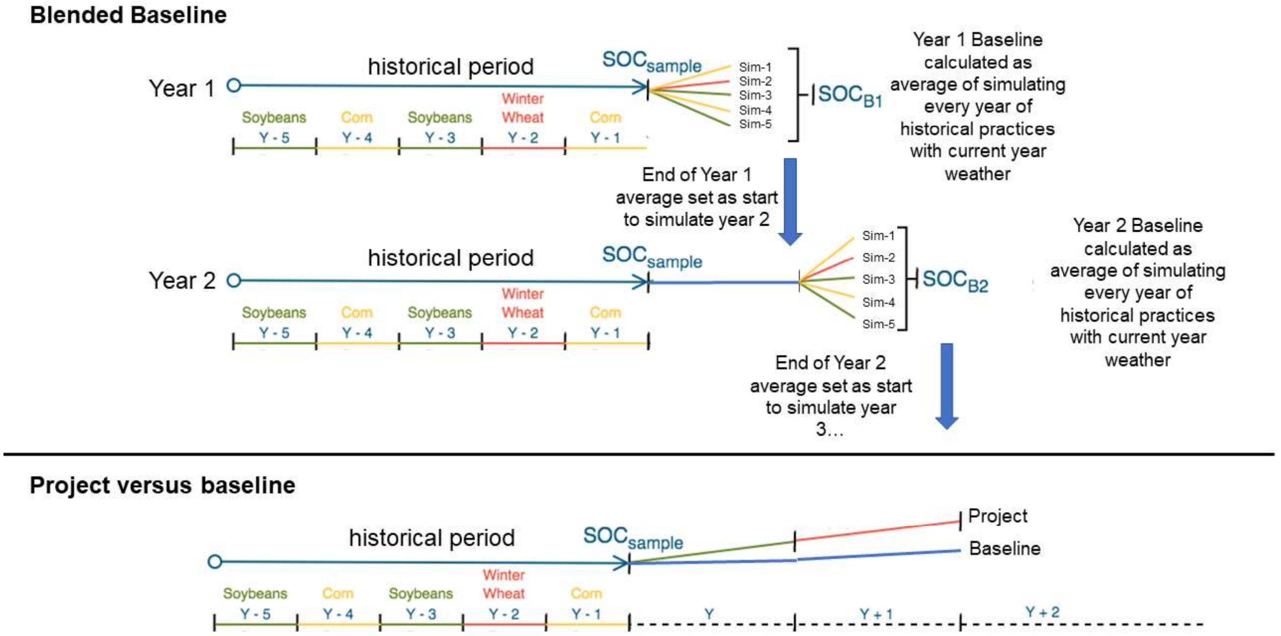

Figure 5.5. Example Diagram for the Blended Baseline Modeling Approach for First 2 Cultivation Cycles of a Crediting Period

5.2 Uncertainty Deduction

If the uncertainty of the estimated emissions reduction is too large, then an uncertainty deduction (UNC_t) is applied by multiplying by 1 – UNC_t. The uncertainty deduction is the extent to which the margin of error of the average emissions reduction exceeds 15% of the estimated average emissions reduction, $\widehat{\overline{ER_t}}$. See Appendix D for detailed guidance on estimating the emissions reduction $\widehat{\overline{ER_t}}$ and the associated uncertainty deduction UNC_t.

Equation 5.1. Uncertainty Deduction

$$\boldsymbol{UNC_t = MIN\left(100\%, MAX\left(0, \frac{\mathrm{ME}_{\widehat{\overline{ER_t}}}}{\widehat{\overline{ER_t}}} - 15\%\right)\right)}$$

Where,			<u>Units</u>
UNC_t	=	Total deduction for uncertainty for cultivation cycle t	
$\widehat{\overline{ER_t}}$	=	Estimated per-acre average emissions reduction across all strata in cultivation cycle t	tCO_2e/acre
$ME_{\widehat{\overline{ER_t}}}$	=	Margin of error of the 95% confidence interval	tCO_2e/acre

5.3 Reversible Emission Reductions

Reversible emission reductions for soil enrichment projects are those related to changes in SOC stocks (as shown in Figure 5.6). The contents of this section describe how reversible emissions reductions are calculated for projects employing either tonne-tonne accounting (TTA) or tonne-year accounting (TYA), as described in Section 3.5, as well as how uncertainty, buffer pool contributions, and reversals are quantified. Projects for which TTA applies must use Equation 5.2a, whereas those applying TYA must use Equation 5.2b. Under TYA, reversible emission reductions are quantified according to the length of time the CO_2e emissions are sequestered and/or contractually secured. Specifically, for each additional tonne of CO_2e that is stored and verified, reversible emissions reductions are accounted for proportionally according to the amount of time for which it has or will be secured relative to the value of the atmospheric impact of maintaining each tonne in the ground for 100 years. This is achieved by multiplying the number of tonnes of additional sequestered CO_2e in a given Reporting Period by 1% per tonne for each year sequestered, based on the assumed time-value of the climate impact of reversible emissions reductions, as described in Section 3.5.6. The commitment to secure CO_2e must be established through a PIA with the Reserve (see Section 3.5.3).

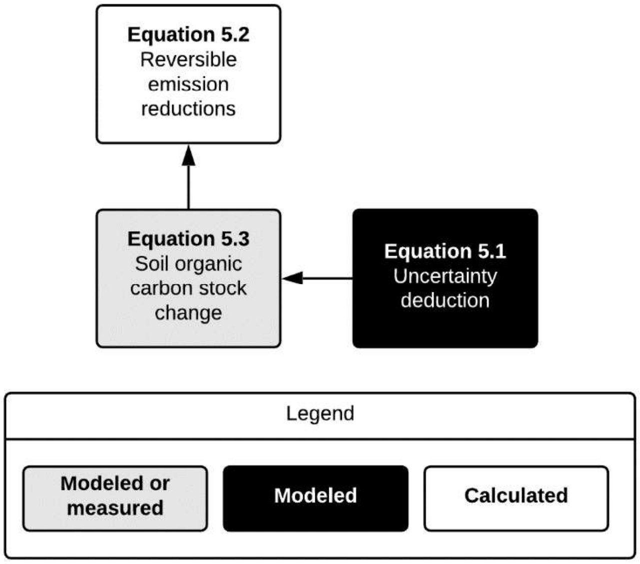

Figure 5.6. Map of Equations Related to the Quantification of Reversible Emission Reductions

Equation 5.2. Reversible GHG Emission Reductions

Equation 5.2a: If applying tonne-tonne accounting, then

$$\boldsymbol{ER_{Rev}} = \sum_{\boldsymbol{t}} \Delta \boldsymbol{CO2\_soil_t}$$

Equation 5.2b: If applying tonne-year accounting, then

$$\boldsymbol{ER_{Rev}} = \sum_{\boldsymbol{t}} (\Delta \boldsymbol{CO2\_soil_t} \times (\boldsymbol{YR_t} + \boldsymbol{CL}) \times \boldsymbol{1\%} - \boldsymbol{PER_t})$$

Where,			Units
ER_{Rev}	=	Total reversible emission reductions for the reporting period	tCO_2e
$\Delta CO2\_soil_t$	=	Carbon dioxide emission reductions from soil organic carbon pool in stratum *s* in cultivation cycle *t*	tCO_2e
YR_t	=	Length of time since the initiation of cultivation cycle *t* in which the additional carbon was sequestered, for each cultivation cycle in which additional carbon was sequestered	years
CL	=	Length of contractual agreement into future from current reporting period that secures all sequestered carbon	years
1%	=	Annual climate impact relative to 100-year permanence timeframe	
PER_t	=	Previous credits issued for cultivation cycle *t*, for each cultivation cycle for which credits were issued	tCO_2e

Box 5.2. Example of Tonne-Year Accounting

If the increase in soil organic carbon stocks was 100 tonnes of CO_2e in the first reporting period, and the Project Owner submits the project report at the end of a one-year first reporting period, and secures the 100 tonnes of CO_2e through a 20 year PIA, then 21 tCO_2e of reversible emissions reductions will be recognized for crediting purposes. This is based on the 20 years for which the tonnes are secured through contract subsequent to the completion of the reporting period and the 1 year for which the tonnes have been already maintained through the first reporting period:

$$\boldsymbol{ER_{Rev} = \sum(100 \times (1 + 20) \times 1\% - 0)}$$

Alternatively, if the first reporting period was 2 years, then 22 tCO_2e would be recognized following verification.

$$\boldsymbol{ER_{Rev} = \sum(100 \times (2 + 20) \times 1\% - 0)}$$

In this second example, the project would have 78 baseline carbon emissions that have not yet been recognized for crediting purposes out of the initial 100 tonnes of CO_2e that were verified. If, in the next year, the contract is extended by another year (so that the PIA still has a term of 20 years total), using the simplified 1% radiative forcing coefficient, another 1 tCO_2e would be converted into a CRT in addition to the prior credits because the project has demonstrated another year toward the 100-year permanence requirement. PIAs may be extended in this way until the end of the contractual commitment reaches a date that is 100 years after the carbon was first sequestered. At that point, credits will have been issued for the 100 tonnes CO_2e sequestered in the first reporting period.

Determining the value to be used for the average carbon stocks in the SOC pool in the project scenario will differ depending on whether the stocks are modeled or directly measured for that reporting period. Where SOC stocks are directly measured, the Project Owner will demonstrate the sampling approach and the steps taken to determine average SOC stocks for each sample unit from the SOC sampling and analysis, as described in Section 6.4. Where SOC stocks are determined through the use of a process-based model, the Project Owner must document the modeling approach used to estimate changes to average SOC stocks over time, as described in Section 6.5. In cases where the SOC stocks are modeled, this quantification will be a function of the input variables of that model (for simplicity, this is not illustrated in Equation 5.3)

Equation 5.3. Soil Organic Carbon Stock Change

$$\boldsymbol{\Delta CO2\_soil_t = \sum_s \left[\left(\overline{\Delta SOC_{wp,s,t}} - \overline{\Delta SOC_{bsl,s,t}}\right) \times A_{s,t}\right] \times (1 - UNC_t)}$$

Where,		Units
$\Delta CO2\_soil_t$	= Carbon dioxide emission reductions from soil organic carbon pool across all strata in cultivation cycle *t*	tCO_2e
$\overline{\Delta SOC_{wp,s,t}}$	= Average change in carbon stocks in the soil organic carbon pool in the project scenario for stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{\Delta SOC_{bsl,s,t}}$	= Average change in carbon stocks in the soil organic carbon pool in the baseline scenario for stratum *s* during cultivation cycle *t*	tCO_2e/acre
$A_{s,t}$	= Area of stratum *s* in cultivation cycle *t*	acres
UNC_t	= Uncertainty in cultivation cycle *t* (Equation 5.1)	

5.3.1 Contribution to the Buffer Pool

For each reporting period, the Project Owner must transfer a quantity of credits (determined by Equation 5.4) to the Reserve Buffer Pool at the time of credit issuance. Credits that enter the buffer pool are held in trust for the benefit of all projects registered with the Reserve, to be used as compensation for unavoidable reversals, as described in Sections 3.5.2 and 5.3.2. Equation 5.4 shall be used to calculate the buffer pool contribution for the project during the reporting period.

At the time of development of this protocol the Reserve was not able to identify any risks of reversal for which the likelihood of occurrence should reasonably be deemed as high. Fires and catastrophic floods would not typically release the carbon that is stored underground. Volcanic activity is exceedingly rare in the conterminous U.S., and does not occur in the areas where crop cultivation typically occurs. Due to the fact that the risk of unavoidable reversals is not significantly differentiated by location or land management, the Reserve has decided to adopt a default buffer pool contribution for all projects that is intended to insure against all types of unavoidable reversals. However, it was determined during the development of the protocol that the geographic concentration of fields in any given project, and indeed across the program as a whole, could exacerbate the GHG impacts of any catastrophic natural reversal event (i.e., If a flood was seen as a reversal risk, and a flood was to occur in a region where project field are concentrated, that could result in significant reversals for the given project). Thus, where more than 50% of a project's acreage is concentrated in a single county, the project must take a higher default deduction for unavoidable reversal risk, as set out Table 5.9 and Equation 5.4 below, of 0.075 and 0.05 respectively for geographically concentrated and dispersed projects.

In addition to the default contribution, projects may be obligated to make additional contributions to the buffer pool in certain situations. Where the Project Owner is a private entity (e.g., an individual, corporation, NGO, etc.), an additional contribution is required to reflect risks from financial failure; the value of $Risk_{FF}$ shall be 0.1. An exception to these rules is made for cases where the Project Owner employs financial mechanisms like insurance or surety bonds, is a public agency or organization, has a contractual agreement identifying a successor entity in the event of the Project Owner's demise (including bankruptcy), in which case the value of $Risk_{FF}$ shall be 0.

For projects using tonne-year accounting, buffer pool contributions are based on the risk of reversals to emissions reductions that have been secured via the PIA, if applicable. Credits issued to such projects based on the length of time any additional sequestered CO_2 has already been maintained are not considered reversible. Using the first example in Box 5.2, the 1 tonne of CO_2e credited based on the completion of the first reporting period is not reversible since that portion of the total amount of sequestered CO_2 represents the time-value of the reversible emission reduction that has already been realized, whereas the 20 tonnes of CO_2e credited based on the commitment of the Project Owner to maintaining sequestered stocks for 20 years under the PIA are reversible and would be the amount used to determine the buffer pool contributions for that reporting period.

Equation 5.4. Buffer Pool Contribution

$$\boldsymbol{Buffer_{rp} = Risk_{Rev,rp} \times ER_{Rev,rp}}$$

Where,			Units
$Buffer_{rp}$	=	Total contribution to the buffer pool for reporting period *rp*	tCO_2e
$Risk_{Rev,rp}$	=	Cumulative risk of reversals for reporting period *rp*, from table 5.3	tCO_2e
$ER_{Rev,rp}$	=	Total reversible emission reductions for the reporting period	tCO_2e

And,

$$\boldsymbol{Risk_{Rev,rp} = 1 - \left[\left(1 - Risk_{default}\right) \times \left(1 - Risk_{FF}\right)\right]}$$

Where,			Units
$Risk_{default}$	=	Default risk of unavoidable reversals, the value is either 0.05 or 0.075, as described in Table 5.9	%
$Risk_{FF}$	=	Additional risk related to financial failure, the value is either 0 or 0.1, as described in Table 5.9	%

As there are only two risk categories that contribute to $Risk_{rev,rp}$, each with two options, there are four possible values for this parameter. The potential project scenarios and the resulting value of $Risk_{rev,rp}$ are listed in Table 5.9.

Table 5.9. Possible Values of $Risk_{rev,rp}$

$Risk_{default}$	Project Owner Entity	Listed Financial Mechanisms	Geographically Dispersed (Y/N)	$Risk_{FF}$	$Risk_{rev, ro}$
0.05	Private	Yes	Y	0	**0.05**
0.05	Public, private with successor entity, accredited land trust	n/a	Y	0	**0.05**
0.075	Any	Yes	N	0	**0.075**
0.05	Private	No	Y	0.1	**0.145**
0.075	Private	No	N	0.1	**0.168**

Project Owners may be able to reduce the risk rating through actions that lower the risk profile of their project. If a project's risk rating declines, the Reserve may distribute previously withheld Buffer Pool CRTs to the Project Owner in proportion to the reduced risk, if the Reserve determines it is appropriate to do so. Similarly, however, the Reserve may require additional contributions to the Buffer Pool if the risk rating increases, to ensure that all CRTs (including those issued in prior years) are properly insured.

5.3.2 Reversals

If a reversal occurs during a reporting period (see Section 3.5), the reversal must be compensated for with CRTs. Specific requirements depend on whether the reversal was avoidable or unavoidable, as described below. Reversal compensation requirements do not apply to emission reductions unrelated to carbon stored in the project area soils (e.g., CH_4 and N_2O).

Identification of a reversal is based on quantified changes in soil carbon stocks across the entire project area. Although soil carbon may be lost on a portion of the project area as a result of changes in practices that release stored carbon stocks, such releases are considered within the full context of the project rather than in isolation. For example, if a single field were enrolled in a stand-alone project and the participating Field Manager discontinued eligible soil enhancement activities, that project would be considered to have experienced an avoidable reversal. However, if that same field were enrolled in an aggregated project comprising many fields, the losses in carbon stocks from that single field would be considered in the full context of all project fields. If GHG reductions from other participating fields are greater than the reversals quantified from the subject field, those losses in soil carbon would not be considered a reversal and would simply be incorporated into the quantification of the project's total net change in soil carbon.

If the project area is subject to a net reversal, then the quantity of soil carbon reversed is considered to be equal to the total net loss of soil carbon across the project, as quantified in Equation 5.2. The quantity of CRTs that must be retired is determined using Equation 5.5, which recognizes the time-value of the CO_2 held out of the atmosphere and in sequestered soil carbon stocks prior to the time of the reversal. As such, Equation 5.5 is not only applicable to all reversible emissions reductions calculated using tonne-tonne accounting (Equation 5.2a), but also to those reversible emissions reductions calculated using tonne-year accounting (Equation 5.2b) that are secured through the term of enforcement for the PIA since they are still considered reversible.

Equation 5.5. Reversals

$$\boldsymbol{Rev} = \sum_{t} \boldsymbol{\Delta CO2\_soil_t} \times \left(\frac{\boldsymbol{Y_p}}{\boldsymbol{100}} - \left(\boldsymbol{Y_{rp}} \times \boldsymbol{0.01} \right) \right)$$

Where,			Units
Rev	=	Quantity of emission reductions affected by the reversal	tCO_2e
$\Delta CO2\_soil_t$	=	Carbon dioxide emission reductions from soil organic carbon pool in stratum *s* in cultivation cycle *t*	tCO_2e
Y_p	=	Length of permanence commitment made by Project Owner (e.g., 100 years for a standard PIA)	years
Y_{rp}	=	Total number of years that have elapsed since the project start date until the first day of the reporting period *rp* when the reversal occurred and, for which CRTs were previously issued	years
1%	=	Annual climate impact relative to 100-year permanence timeframe	%

Under this protocol, credits are considered reversed in the opposite order in which the credit was quantified and verified. For example, suppose a project was credited for 100 tonnes of reversible emissions reductions in year 1 and another 50 tonnes in year 2. In year 3, a reversal occurs that releases 75 tonnes of emissions into the atmosphere (based on application of Equation 5.5). In this situation, the 50 credits issued in year 2 are considered reversed, along with 25 of the credits issued in year 1. Furthermore, for quantification purposes, a reversal is assumed to have occurred at the start of the reporting period during which it occurred, regardless when during the reporting period it actually occurred.

5.3.2.1 Compensating for Avoidable Reversals

Requirements for avoidable reversals are as follows:

1. If an avoidable reversal is identified during annual monitoring, the Project Owner must give written notice to the Reserve within thirty days of identifying the reversal. Alternatively, if the Reserve determines that an avoidable reversal has occurred, it shall deliver written notice to the Project Owner. Within thirty days of receiving the avoidable

reversal notice from the Reserve, the Project Owner must provide a written description and explanation of the reversal to the Reserve, including a map of the specific area(s) for which there has been a reversal.

2. Within a year of notifying the Reserve of a reversal, or receiving the avoidable reversal notice from the Reserve, the Project Owner must:
    a. provide the Reserve with a verified estimate of current SOC stocks. A site visit to the field(s) that are the cause of the reversal is not required, though verifiers may choose to visit such fields based on a field-level risk evaluation performed while selecting locations for site visits (see Section 8.4.1), and
    b. transfer to the Reserve a quantity of CRTs from its Reserve account equal to the size of any avoidable reversal as calculated in Equation 5.5., or, if the project expects to accumulate sufficient SOC changes in the following reporting period, the reversal may be carried forward to the next reporting period as "negative carryover" and applied as an adjustment to the volume of CRTs to be issued in the next reporting period.
3. The surrendered CRTs must be those that were issued to the soil enrichment project, or that were issued to other soil enrichment projects registered with the Reserve. If there is not a sufficient quantity of soil enrichment CRTs available for compensation, as determined by the Reserve, any other CRTs are acceptable.
4. The surrendered CRTs shall be retired or cancelled by the Reserve and designated in the Reserve software as compensating for an avoidable reversal.

5.3.2.2 Compensating for Unavoidable Reversals

Requirements for unavoidable reversals are as follows:

1. If the Project Owner determines there has been an unavoidable reversal, it must notify the Reserve in writing of the unavoidable reversal within 30 days of identifying the reversal.
2. The Project Owner must explain the nature of the unavoidable reversal, including a map of the specific area affected, and provide an estimate of the size of the reversal using Equation 5.5.

If the Reserve determines that there has been an unavoidable reversal, it shall retire a quantity of CRTs from the Reserve Buffer Pool equal to the size of the reversal in metric tons of CO_2.

5.4 Non-Reversible Emission Reductions

Non-reversible emission reductions for soil enrichment projects are those unrelated to changes in SOC stocks, such as reduced N_2O emission from fertilizer use or reduced CH_4 emissions from water management. Figure 5.7 illustrates the relationships between the equations used to quantify non-reversible emission reductions.

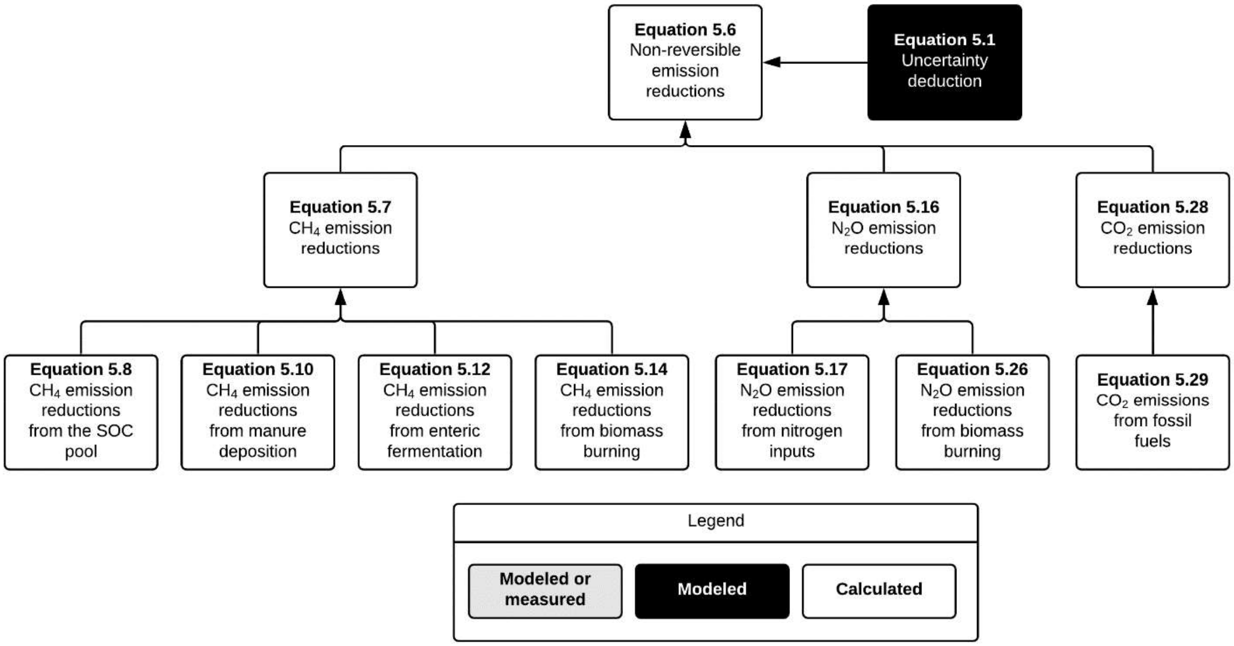

Figure 5.7. Map of Equations Related to the Quantification of Non-Reversible Emission Reductions

The sources and methods for quantification are the same in the baseline and project scenarios. The remaining equations in this section can be applied in either scenario. Thus, they are not presented here twice. Rather, project developers should add subscripts as needed to denote whether the parameters and results are relevant to the baseline scenario ("bsl") or the project scenario ("pr"). Emission reductions are calculated for each source, with specific equations denoting the point at which baseline and project emissions are compared.

Equation 5.6. Non-Reversible Emission Reductions

$$\boldsymbol{ER_{NonRev}} = \sum_{s} \left[\left(\overline{\boldsymbol{\Delta CH4_{s,t}}} + \overline{\boldsymbol{\Delta N2O_{s,t}}} + \overline{\boldsymbol{\Delta CO2\_NR_{s,t}}} \right) \times \boldsymbol{A_{s,t}} \times \left(\boldsymbol{1} - \boldsymbol{LE_{s,t}} \right) \right] \times (\boldsymbol{1} - UNC_t)$$

Where,			Units
ER_{NonRev}	=	Total non-reversible emission reductions for the reporting period	tCO2e
$\overline{\Delta CH4_{s,t}}$	=	Average methane emission reductions in stratum *s* during cultivation cycle *t* (Equation 5.7)	tCO2e/acre
$\overline{\Delta N2O_{s,t}}$	=	Average nitrous oxide emission reductions in stratum *s* during cultivation cycle *t* (Equation 5.16)	tCO2e/acre
$\overline{\Delta CO2\_NR_{s,t}}$	=	Average carbon dioxide emission reductions from fossil fuel use in stratum *s* during cultivation cycle *t* (Equation 5.28)	tCO2e/acre
$A_{s,t}$	=	Area of stratum *s* in cultivation cycle *t*	acres
UNC_t	=	Uncertainty deduction for cultivation cycle *t* (Equation 5.1)	

5.4.1 Methane Emissions

Sources of methane emissions in a soil enrichment project include methanogenesis in the soil (Equation 5.9), manure deposited by grazing animals (Equation 5.10), enteric fermentation in grazing animals (Equation 5.12), and biomass burning (Equation 5.14). Figure 5.8 illustrates the relationships between the equations used to quantify methane emission reductions.

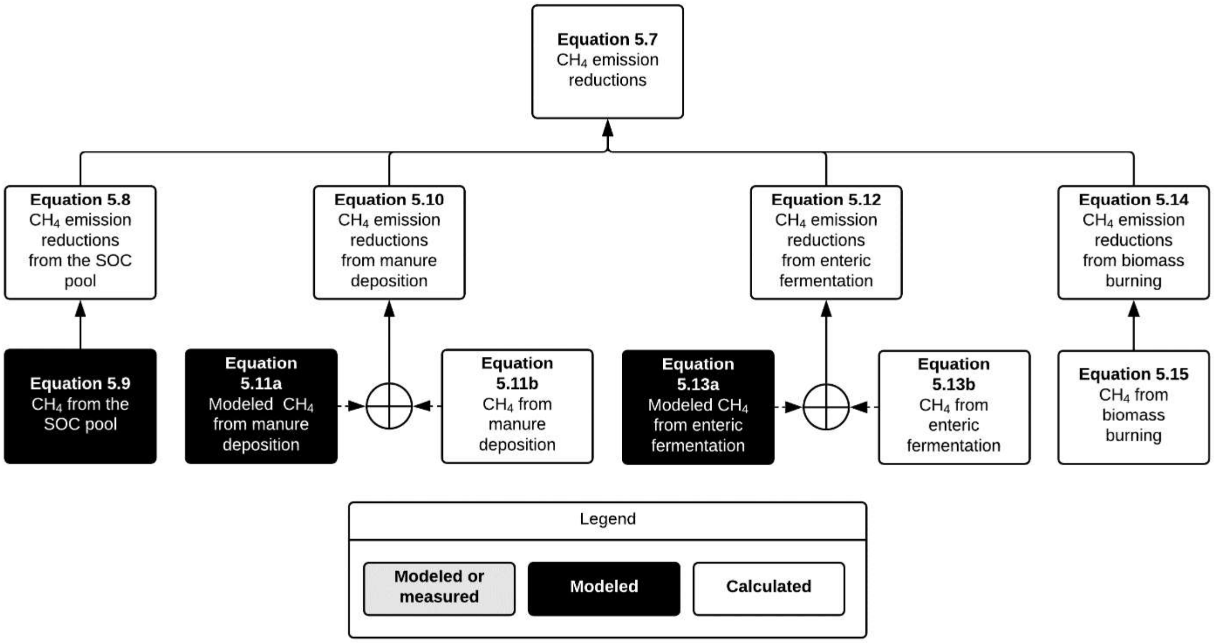

Figure 5.8. Map of Equations Related to the Quantification of Methane Emission Reductions

Equation 5.7. Methane Emission Reductions

$$\overline{\Delta \boldsymbol{CH4}_{s,t}} = \overline{\Delta \boldsymbol{CH4\_soil}_{s,t}} + \overline{\Delta \boldsymbol{CH4\_md}_{s,t}} + \overline{\Delta \boldsymbol{CH4\_ent}_{s,t}} + \overline{\Delta \boldsymbol{CH4\_bb}_{s,t}}$$

Where,			Units
$\overline{\Delta CH4_{s,t}}$	=	Average methane emission reductions in stratum *s* during cultivation cycle *t*	tCO2e/acre
$\overline{\Delta CH4\_soil_{s,t}}$	=	Average methane emission reductions from the soil organic carbon pool in stratum *s* during cultivation cycle *t* (Equation 5.8)	tCO2e/acre
$\overline{\Delta CH4\_md_{s,t}}$	=	Average methane emission reductions from manure deposition in stratum *s* during cultivation cycle *t* (Equation 5.10)	tCO2e/acre
$\overline{\Delta CH4\_ent_{s,t}}$	=	Average methane emission reductions from enteric fermentation in stratum *s* during cultivation cycle *t* (Equation 5.12)	tCO2e/acre
$\overline{\Delta CH4\_bb_{s,t}}$	=	Average methane emission reductions from biomass burning in stratum *s* during cultivation cycle *t* (Equation 5.14)	tCO2e/acre

Depending upon nutrient inputs and weather conditions, methanogenic bacteria in the soil will convert some amount of organic matter into CH_4. This activity is affected by agricultural management practices and may be estimated through the use of a model, as shown in Equation 5.9.

Equation 5.8. Methane Emission Reductions from the Soil Organic Carbon Pool

$$\overline{\boldsymbol{\Delta CH4\_soil_{s,t}}} = \overline{\boldsymbol{CH4\_soil_{bsl,s,t}}} - \overline{\boldsymbol{CH4\_soil_{pr,s,t}}}$$

Where,

			Units
$\overline{\Delta CH4\_soil_{s,t}}$	=	Average methane emission reductions from the soil organic carbon pool in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{CH4\_soil_{bsl,s,t}}$	=	Average baseline methane emissions from the soil organic carbon pool in stratum *s* during cultivation cycle *t* (Equation 5.9)	tCO_2e/acre
$\overline{CH4\_soil_{pr,s,t}}$	=	Average project methane emissions from the soil organic carbon pool in stratum *s* during cultivation cycle *t* (Equation 5.9)	tCO_2e/acre

Equation 5.9. Methane Emissions from the Soil Organic Carbon Pool

$$\overline{\boldsymbol{CH4\_soil_{s,t}}} = f_{\boldsymbol{CH4SOC}}(\boldsymbol{Var\ A_{s,t}}, \boldsymbol{Var\ B_{s,t}}, \ldots) \times \boldsymbol{GWP_{CH4}}$$

Where,

			Units
$\overline{CH4\_soil_{s,t}}$	=	Average methane emissions from the soil organic carbon pool in stratum *s* during cultivation cycle *t*	tCO_2e/acre
f_{CH4SOC}	=	Model predicting methane emissions from the soil organic carbon pool	tCH_4/acre
$Var\ A_{s,t}$	=	Value of model input variable A in the baseline scenario for stratum *s* in cultivation cycle *t*	
$Var\ B_{s,t}$	=	Value of model input variable B in the baseline scenario for stratum *s* in cultivation cycle *t*	
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4

Where livestock graze in the project area, they will deposit manure on the soil. This may occur in the baseline scenario, project scenario, or both. Equation 5.10 quantifies the CH_4 emissions from this manure deposition, caused by anaerobic bacteria. This source of CH_4 may be quantified either with a model (Equation 5.11a) or using default values and project data (Equation 5.11b).

Equation 5.10. Methane Emission Reductions from Manure Deposition

$$\overline{\boldsymbol{\Delta CH4\_md_{s,t}}} = \overline{\boldsymbol{CH4\_md_{bsl,s,t}}} - \overline{\boldsymbol{CH4\_md_{pr,s,t}}}$$

Where,

			Units
$\overline{\Delta CH4\_md_{s,t}}$	=	Average methane emission reductions from manure deposition in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{CH4\_md_{bsl,s,t}}$	=	Average baseline methane emissions from manure deposition in stratum *s* during cultivation cycle *t* (Equation 5.11)	tCO_2e/acre
$\overline{CH4\_md_{pr,s,t}}$	=	Average project methane emissions from manure deposition in stratum *s* during cultivation cycle *t* (Equation 5.11)	tCO_2e/acre

Equation 5.11. Methane Emissions from Manure Deposition

Equation 5.11a: Modeled methane emissions from manure deposition

$$\overline{\boldsymbol{CH4\_md_{s,t}}} = \mathfrak{f}_{\boldsymbol{CH4md}}(\boldsymbol{Var\ A_{s,t}}, \boldsymbol{Var\ B_{s,t}}, \ldots) \times \boldsymbol{GWP_{CH4}}$$

Where,			Units
$\overline{CH4\_md_{s,t}}$	=	Average methane emissions from manure deposition in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\mathfrak{f}_{CH4md}$	=	Model predicted methane emissions from manure deposition	tCH_4/acre
$Var\ A_{i,t}$	=	Value of model input variable A in the baseline scenario for stratum *s* in cultivation cycle *t*	
$Var\ B_{s,t}$	=	Value of model input variable B in the baseline scenario for stratum *s* in cultivation cycle *t*	
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4

Equation 5.11b: Calculated methane emissions from manure deposition

$$\overline{\boldsymbol{CH4\_md_{s,t}}} = \sum_{\boldsymbol{L}} \left(\boldsymbol{AGD_{l,s,t}} \times \boldsymbol{VS_l} \times \boldsymbol{B_{0,l}}\right) \times \frac{\boldsymbol{MCF_{PRP}} \times \boldsymbol{\rho_{CH_4}} \times \boldsymbol{GWP_{CH_4}}}{\boldsymbol{1000}} \times \frac{\boldsymbol{1}}{\boldsymbol{A_s}}$$

Where,			Units
$\overline{CH4\_md_{s,t}}$	=	Average methane emissions from manure deposition in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$AGD_{l,s,t}$	=	Animal grazing days for livestock category *l*, in stratum *s*, during cultivation cycle *t* (see Box 5.3)	animal days
VS_l	=	Volatile solids excreted by grazing animals in category *l*	kg VS/animal/day
$B_{0,l}$	=	Maximum methane potential for manure from category *l*	m^3 CH_4/kg VS
MCF_{PRP}	=	Methane conversion factor for pasture/range/paddock manure management, dependent on average temperature during grazing season	%
ρ_{CH4}	=	Density of methane at 1 atm and the average temperature during the grazing season	kg/m^3
1000	=	Conversion factor	kg/t
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4
A_s	=	Area of stratum *s*	acres

Box 5.3. Determining Animal Grazing Days (AGD_l)

Equation 5.10 and Equation 5.12 require the use of parameter AGD_l, which represents the total number of days that were grazed by a single category of animals. This is the sum of the number of days each animal category was grazed during the relevant time period. A simplified example is below:

Animal Category	Population	Grazing Days	Animal Grazing Days
Bulls	100	240	24,000
Beef Cows	200	240	48,000
Beef Replacements	40	240	9,600

Note: the numbers in this table are fictional used only for illustrative purposes

If the population of each category is not stable over the grazing period, a reasonable approach shall be applied to estimate AGD_l for each category over the relevant time period.

Where ruminant livestock graze in the project area, they will also generate CH_4 through enteric fermentation. This may occur in the baseline scenario, project scenario, or both. Equation 5.12 quantifies the CH_4 emissions from this enteric fermentation, caused by anaerobic gut bacteria. This source of CH_4 may be quantified either with a model (Equation 5.13a) or using default values and project data (Equation 5.13b).

Equation 5.12. Methane Emission Reductions from Enteric Fermentation

$$\overline{\Delta CH4\_ent_{s,t}} = \overline{CH4\_ent_{bsl,s,t}} - \overline{CH4\_ent_{pr,s,t}}$$

Where,			Units
$\overline{\Delta CH4\_ent_{s,t}}$	=	Average methane emission reductions from enteric fermentation in stratum *s* during cultivation cycle *t*	$tCO_2e/acre$
$\overline{CH4\_ent_{bsl,s,t}}$	=	Average baseline methane emissions from enteric fermentation in stratum *s* during cultivation cycle *t* (Equation 5.13)	$tCO_2e/acre$
$\overline{CH4\_ent_{pr,s,t}}$	=	Average project methane emissions from enteric fermentation in stratum *s* during cultivation cycle *t* (Equation 5.13)	$tCO_2e/acre$

Equation 5.13. Methane Emissions from Enteric Fermentation

Equation 5.13a: Modeled methane emissions from enteric fermentation

$$\overline{\boldsymbol{CH4\_ent_{s,t}}} = \mathfrak{f}_{\boldsymbol{CH4ent}}(\boldsymbol{Var\ A_{s,t}}, \boldsymbol{Var\ B_{s,t}}, \ldots) \times \boldsymbol{GWP_{CH4}}$$

Where,			Units
$\overline{CH4\_ent_{s,t}}$	=	Average methane emissions from enteric fermentation in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\mathfrak{f}_{CH4md}$	=	Model predicting methane emissions from enteric fermentation	tCH_4/acre
$Var\ A_{s,t}$	=	Value of model input variable A in the baseline scenario for stratum *s* in cultivation cycle *t*	
$Var\ B_{s,t}$	=	Value of model input variable B in the baseline scenario for stratum *s* in cultivation cycle *t*	
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4

Equation 5.13b: Calculated methane emissions from enteric fermentation

$$\overline{\boldsymbol{CH4\_ent_{s,t}}} = \sum_{\boldsymbol{L}} \left(\boldsymbol{AGD_{l,s,t}} \times \boldsymbol{PEF_{ENT,l}}\right) \times \frac{\boldsymbol{1}}{\boldsymbol{A_s}} \times \frac{\boldsymbol{GWP_{CH_4}}}{\boldsymbol{1000}}$$

Where,			Units
$\overline{CH4\_ent_{s,t}}$	=	Average methane emissions from enteric fermentation in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$AGD_{l,s,t}$	=	Animal grazing days for livestock category *l*, in stratum *s*, during cultivation cycle *t* (see Box 5.3)	animal days
$PEF_{ENT,l}$	=	Project emission factor for enteric methane emissions from livestock category *l* in the project state[19]	kg CH_4/head/day
A_s	=	Area of stratum *s*	acres
1000	=	Conversion factor	kg/t
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4

Where there is fire on the project area, either in the baseline or project scenario, some portion of the organic matter will be converted to CH_4 as a byproduct of the combustion process. Equation 5.14 and Equation 5.15 quantify this gas and source using default emission factors combined with an estimate of the mass of aboveground dry matter in the area affected by fire. Emission reductions associated with reductions in the use of fire to manage crop residues can be credited for, if attributable to reductions in yield of the crop, or livestock grazing of such residues. If reduced use of fire is attributed to crop residues being left in the field to decay, then no emission reductions can be credited for such emissions during the given reporting period.

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[19] Default emission factors and parameters can be found in a separate document, *Soil Enrichment Project Parameters*, available at: http://www.climateactionreserve.org/how/protocols/soil-enrichment/.

Equation 5.14. Methane Emission Reductions from Biomass Burning

$$\overline{\Delta CH4\_bb_{s,t}} = \overline{CH4\_bb_{bsl,s,t}} - \overline{CH4\_bb_{pr,s,t}}$$

Where,			Units
$\overline{\Delta CH4\_bb_{s,t}}$	=	Average methane emission reductions from biomass burning in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{CH4\_bb_{bsl,s,t}}$	=	Average baseline methane emissions from biomass burning in stratum *s* during cultivation cycle *t* (Equation 5.15)	tCO_2e/acre
$\overline{CH4\_bb_{pr,s,t}}$	=	Average project methane emissions from biomass burning in stratum *s* during cultivation cycle *t* (Equation 5.15)	tCO_2e/acre

Equation 5.15. Methane Emissions from Biomass Burning

$$\overline{CH4\_bb_{s,t}} = \frac{\sum_{c=1}^{C} MB_{c,s,t} \times CF_c \times EF_{c,CH4}}{A_s} \times \frac{1}{10^6} \times GWP_{CH4}$$

Where,			Units
$\overline{CH4\_bb_{s,t}}$	=	Average methane emissions from biomass burning in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$MB_{c,i,t}$	=	Mass of agricultural residues of type *c* burned in stratum *s* in cultivation cycle *t*	kg
CF_c	=	Combustion factor for agricultural residue type *c*, based on proportion of pre-fire fuel biomass consumed	
$EF_{c,CH4}$	=	Methane emission factor for the burning of agricultural residue type *c*	gCH_4/kg dry matter burnt
A_s	=	Area of stratum *s*	acres
GWP_{CH4}	=	Global warming potential for CH_4 (Table 5.1)	tCO_2e/tCH_4

5.4.2 Nitrous Oxide Emissions

Sources of nitrous oxide emissions in a soil enrichment project include fertilizer use (Equation 5.19), manure deposited by grazing animals (Equation 5.22), use of N-fixing species (Equation 5.25), and biomass burning (Equation 5.26). Figure 5.9 illustrates the relationships between the equations used to quantify N_2O emission reductions).

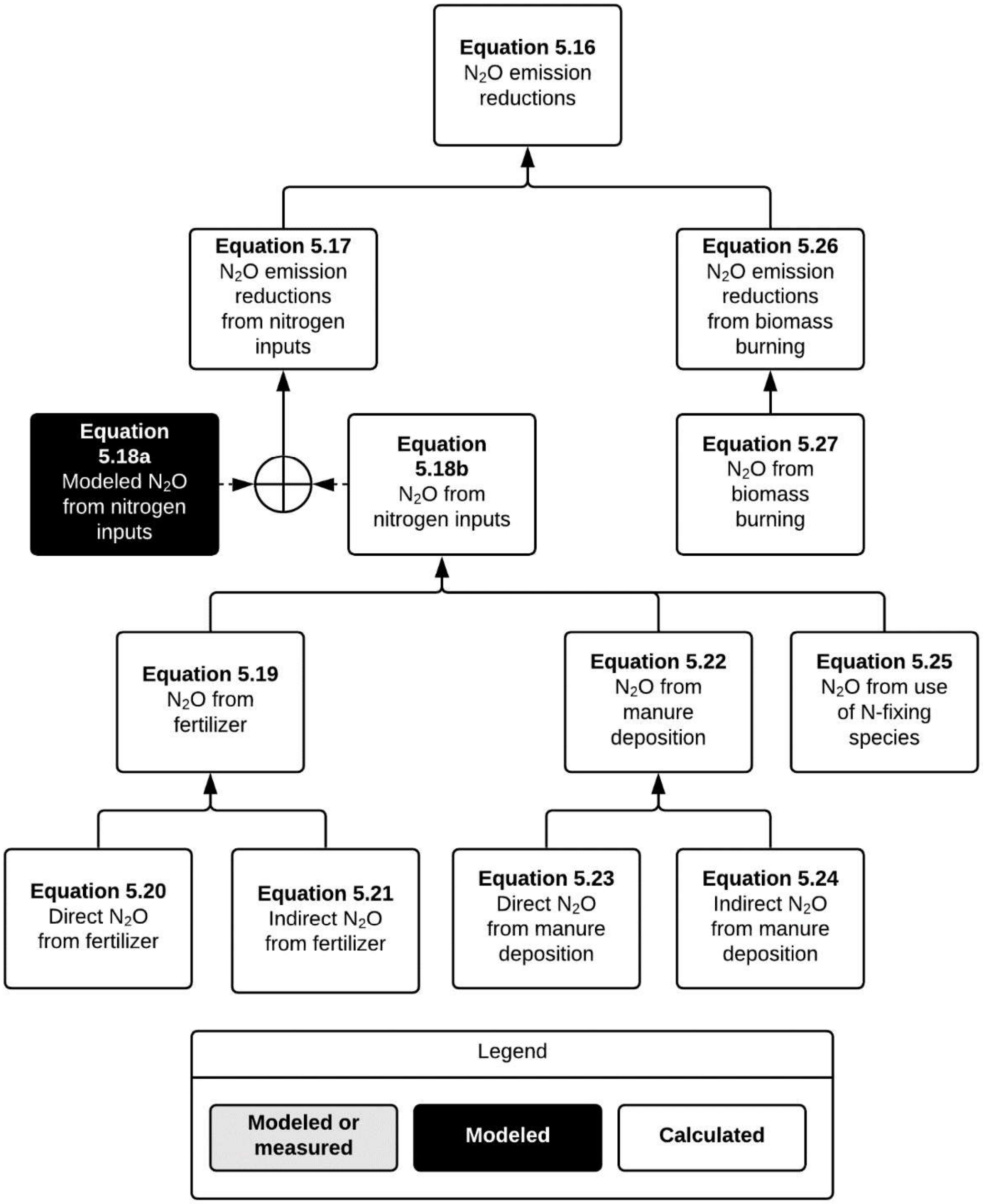

Figure 5.9. Map of Equations Related to the Quantification of Nitrous Oxide Emission Reductions

Equation 5.16. Nitrous Oxide Emission Reductions

$$\boldsymbol{\overline{\Delta N2O_{s,t}} = \overline{\Delta N2O\_input_{s,t}} + \overline{\Delta N2O\_bb_{s,t}}}$$

Where,			Units
$\overline{\Delta N2O_{s,t}}$	=	Average nitrous oxide emission reductions in stratum *s* in cultivation cycle *t*	$tCO_2e/acre$
$\overline{\Delta N2O\_input_{s,t}}$	=	Average nitrous oxide emission reductions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t* (Equation 5.17)	$tCO_2e/acre$
$\overline{\Delta N2O\_bb_{s,t}}$	=	Average nitrous oxide emission reductions due to biomass burning in stratum *s* in cultivation cycle *t* (Equation 5.28)	$tCO_2e/acre$

Equation 5.17. Nitrous Oxide Emission Reductions from Nitrogen Inputs

$$\boldsymbol{\overline{\Delta N2O\_input_{s,t}} = \overline{N2O\_input_{bsl,s,t}} - \overline{N2O\_input_{pr,s,t}}}$$

Where,			Units
$\overline{\Delta N2O\_input_{s,t}}$	=	Average nitrous oxide emission reductions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t*	$tCO_2e/acre$
$\overline{N2O\_input_{bsl,s,t}}$	=	Average baseline nitrous oxide emissions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t* (Equation 5.18)	$tCO_2e/acre$
$\overline{N2O\_input_{pr,s,t}}$	=	Average project nitrous oxide emissions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t* (Equation 5.18)	$tCO_2e/acre$

N_2O emissions from nitrogen inputs on the project area are quantified for both the baseline and project scenarios using Equation 5.18. These emissions may be quantified using a model (Equation 5.18a) or through default values and project data (Equation 5.18b).

Equation 5.18. Nitrous Oxide Emissions from Nitrogen Inputs

Equation 5.18a: Modeled nitrous oxide emissions from nitrogen inputs

$$\overline{\boldsymbol{N2O\_input_{s,t}}} = \mathfrak{f}_{\boldsymbol{N2Oinput}}(\boldsymbol{Var\ A_{s,t}}, \boldsymbol{Var\ B_{s,t}}, \dots) \times \boldsymbol{GWP_{N2O}}$$

Where,			Units
$\overline{N2O\_input_{s,t}}$	=	Average nitrous oxide emissions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$\mathfrak{f}_{N2Oinput}$	=	Model predicting nitrous oxide emissions from nitrogen inputs	tN_2O/acre
$Var\ A_{s,t}$	=	Value of model input variable A in stratum *s* in cultivation cycle *t*	
$Var\ B_{s,t}$	=	Value of model input variable B in stratum *s* in cultivation cycle *t*	
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

Equation 5.18b: Calculated nitrous oxide emissions from nitrogen inputs

$$\overline{\boldsymbol{N2O\_input_{s,t}}} = \frac{\boldsymbol{N2O\_fert_{s,t}} + \boldsymbol{N2O\_md_{s,t}} + \boldsymbol{N2O\_Nfix_{s,t}}}{\boldsymbol{A_s}}$$

Where,			Units
$\overline{N2O\_input_{s,t}}$	=	Average nitrous oxide emissions due to nitrogen inputs to soils in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$N2O\_fert_{s,t}$	=	Nitrous oxide emissions due to fertilizer use in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$N2O\_md_{s,t}$	=	Nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$N2O\_Nfix_{s,t}$	=	Nitrous oxide emissions from all crop residues (including those from N-fixing species) in stratum *s* in cultivation cycle *t*	tCO_2e/acre
A_s	=	Area of stratum *s*	acres

Application of organic or synthetic fertilizers to the project area will result in both direct and indirect emissions of N_2O (Equation 5.19).

Equation 5.19. Nitrous Oxide Emissions from Fertilizer

$$\boldsymbol{N2O\_fert_{s,t}} = \boldsymbol{N2O\_fert_{direct,s,t}} + \boldsymbol{N2O\_fert_{indirect,s,t}}$$

Where,			Units
$N2O\_fert_{s,t}$	=	Nitrous oxide emissions due to fertilizer use in stratum *s* n cultivation cycle *t*	tCO_2e/acre
$N2O\_fert_{direct,s,t}$	=	Direct nitrous oxide emissions due to fertilizer use in stratum *s* in cultivation cycle *t* (Equation 5.20)	tCO_2e/acre
$N2O\_fert_{indirect,s,t}$	=	Indirect nitrous oxide emissions due to fertilizer use in stratum *s* in cultivation cycle *t* (Equation 5.21)	tCO_2e/acre

Direct N_2O emissions from fertilizer application are quantified according to Equation 5.20.

Equation 5.20. Direct Nitrous Oxide Emissions from Fertilizer

$$\boldsymbol{N2O\_fert_{direct,s,t} = \left(M_{SF,s,t} \times NC_{SF} + M_{OF,s,t} \times NC_{OF}\right) \times EF_{Ndirect} \times \frac{44}{28} \times GWP_{N2O}}$$

Where,			Units
$N2O\_fert_{direct,s,t}$	=	Direct nitrous oxide emissions due to fertilizer use in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$M_{SF,s,t}$	=	Mass of N containing synthetic fertilizer applied for stratum *s* in cultivation cycle *t*	t
NC_{SF}	=	N content of baseline synthetic fertilizer applied	tN/t fertilizer
$M_{OF,s,t}$	=	Mass of N containing organic fertilizer applied for stratum *s* in cultivation cycle *t*	t
NC_{OF}	=	N content of baseline organic fertilizer applied	tN/t fertilizer
$EF_{Ndirect}$	=	Emission factor for nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues	tN_2O/t N applied
$\frac{44}{28}$	=	Molar mass ratio of N_2O to N	kg N_2O/kg N_2O-N
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

Indirect N_2O emissions from fertilizer application (due to leaching, volatilization, and run-off) are quantified according to Equation 5.21.

Equation 5.21. Indirect Nitrous Oxide Emissions from Fertilizer

$$\begin{aligned}\boldsymbol{N2O\_fert_{indirect,s,t}} &= \left[\left(\boldsymbol{M_{SF,s,t}} \times \boldsymbol{NC_{SF}} \times \boldsymbol{Frac_{GASF}} + \boldsymbol{M_{OF,s,t}} \times \boldsymbol{NC_{OF}} \times \boldsymbol{Frac_{GASM}}\right) \times \boldsymbol{EF_{Nvolat}} \right.\\ &\left. + \left(\boldsymbol{M_{SF,s,t}} \times \boldsymbol{NC_{SF}} + \boldsymbol{M_{OF,s,t}} \times \boldsymbol{NC_{OF}}\right) \times \boldsymbol{Frac_{LEACH}} \times \boldsymbol{EF_{Nleach}}\right] \times \frac{\mathbf{44}}{\mathbf{28}} \times \boldsymbol{GWP_{N2O}}\end{aligned}$$

Where,

			Units
$N2O\_fert_{indirect,s,t}$	=	Indirect nitrous oxide emissions due to fertilizer use in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$M_{SF,s,t}$	=	Mass of N containing synthetic fertilizer applied for stratum *s* in cultivation cycle *t*	t
NC_{SF}	=	N content of baseline synthetic fertilizer applied	tN/t fertilizer
$M_{OF,s,t}$	=	Mass of N containing organic fertilizer applied for stratum *s* in cultivation cycle *t*	t
NC_{OF}	=	N content of baseline organic fertilizer applied	tN/t fertilizer
$Frac_{GASF}$	=	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NO_x	
$Frac_{GASM}$	=	Fraction of all organic N added to soils that volatilizes as NH_3 and NO_x	
EF_{Nvolat}	=	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces	tN_2O-N /(t NH_3-N + NOx-N volatilized)
$Frac_{LEACH}$	=	Fraction of N added (synthetic or organic) to soils that is lost through leaching and runoff, in regions where leaching and runoff occurs. Equal to 0 where average annual precipitation is less than potential evapotranspiration, except where irrigation is employed.	tN_2O-N / t N leached and runoff
EF_{Nleach}	=	Emission factor for nitrous oxide emissions from leaching and runoff	
$\frac{44}{28}$	=	Molar mass ratio of N_2O to N	kg N_2O/kg N_2O-N
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

Equation 5.22. Nitrous Oxide Emissions from Manure Deposition

$$\boldsymbol{N2O\_md_{s,t}} = \boldsymbol{N2O\_md_{direct,s,t}} + \boldsymbol{N2O\_md_{indirect,s,t}}$$

Where,

			Units
$N2O\_md_{s,t}$	=	Nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$N2O\_md_{direct,s,t}$	=	Direct nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t* (Equation 5.23)	tCO_2e/acre
$N2O\_md_{indirect,s,t}$	=	Indirect nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t* (Equation 5.24)	tCO_2e/acre

Equation 5.23. Direct Nitrous Oxide Emissions from Manure Deposition

$$\boldsymbol{N2O\_md_{direct,s,t}} = \sum_{L}\left(\boldsymbol{AGD_l} \times \boldsymbol{Nex_l} \times \boldsymbol{EF_{N2O,md,l}}\right) \times \frac{\mathbf{44}}{\mathbf{28}} \times \frac{\boldsymbol{GWP_{N_2O}}}{\mathbf{1000}}$$

Where,

			Units
$N2O\_md_{direct,s,t}$	=	Direct nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$AGD_{l,s,t}$	=	Animal grazing days for livestock category *l*, in stratum *s*, during cultivation cycle *t* (see Box 5.3)	animal days
Nex_l	=	Nitrogen excreted by grazing animals in livestock category *l*	kg N/head/day
$EF_{N2O,md,l}$	=	Emission factor for nitrous oxide from manure and urine deposited on soils by livestock type *l*	kg N_2O-N/kg N input
$\frac{44}{28}$	=	Molar mass ratio of N_2O to N	kg N_2O/kg N_2O-N
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O
1000	=	Conversion factor	kg/t

Equation 5.24. Indirect Nitrous Oxide Emissions from Manure Deposition

$$\begin{aligned}\boldsymbol{N2O\_md_{indirect,s,t}} &\\ = \Big[&(\boldsymbol{AGD_l} \times \boldsymbol{Nex_l} \times \boldsymbol{Frac_{GASMD}}) \times \boldsymbol{EF_{Nvolat}} \\ &+ \left(\boldsymbol{AGD_{l,i,t}} \times \boldsymbol{Nex_l}\right) \times \boldsymbol{Frac_{LEACHMD}} \times \boldsymbol{EF_{Nleach}}\Big] \times \frac{\mathbf{44}}{\mathbf{28}} \times \boldsymbol{GWP_{N2O}}\end{aligned}$$

Where,

			Units
$N2O\_md_{indirect,s,t}$	=	Indirect nitrous oxide emissions due to manure deposition in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$AGD_{l,s,t}$	=	Animal grazing days for livestock category *l*, in stratum *s*, during cultivation cycle *t* (see Box 5.3)	animal days
Nex_l	=	Nitrogen excreted by grazing animals in livestock category *l*	kg N/head/day
$Frac_{GASMD}$	=	Fraction of manure N added to soils that volatilizes as NH_3 and NO_x	
EF_{Nvolat}	=	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces	tN_2O-N /(t NH_3-N + NOx-N volatilized)
$Frac_{LEACHMD}$	=	Fraction of manure N added to soils that is lost through leaching and runoff, in regions where leaching and runoff occurs. Equal to 0 where average annual precipitation is less than potential evapotranspiration, unless irrigation is employed.	tN_2O-N / t N leached and runoff
EF_{Nleach}	=	Emission factor for nitrous oxide emissions from leaching and runoff	
$\frac{44}{28}$	=	Molar mass ratio of N_2O to N	kg N_2O/kg N_2O-N
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

Equation 5.25. Nitrous Oxide Emissions from the Incorporation of All Crop Residues

$$\boldsymbol{N2O\_Nfix_{s,t} = \sum_{g} \left(MB_{g,s,t} \times N_{content,g}\right) \times EF_{Ndirect} \times 44/28 \times GWP_{N2O}}$$

Where,			Units
$N2O\_Nfix_{s,t}$	=	Nitrous oxide emissions from all crop residues (including those from N-fixing species) for stratum *s* in cultivation cycle *t*	tCO_2e/acre
$MB_{g,s,t}$	=	Annual dry matter, including aboveground and below ground, of N-fixing species *g* returned to soils for stratum *s* in cultivation cycle *t*	t dm
$N_{content,g}$	=	Fraction of N in dry matter for plant species *g*	t N/t dm
$EF_{Ndirect}$	=	Emission factor for nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues	tN_2O/tN applied
$\frac{44}{28}$	=	Molar mass ratio of N_2O to N	kg N_2O/kg N_2O-N
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

Equation 5.26. Nitrous Oxide Emission Reductions from Biomass Burning

$$\boldsymbol{\overline{\Delta N2O\_bb_{s,t}} = \overline{N2O\_bb_{bsl,s,t}} - \overline{N2O\_bb_{pr,s,t}}}$$

Where,			Units
$\overline{\Delta N2O\_bb_{s,t}}$	=	Average nitrous oxide emission reductions from biomass burning in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{N2O\_bb_{bsl,s,t}}$	=	Average baseline nitrous oxide emissions from biomass burning in stratum *s* during cultivation cycle *t* (Equation 5.27)	tCO_2e/acre
$\overline{N2O\_bb_{pr,s,t}}$	=	Average project nitrous oxide emissions from biomass burning in stratum *s* during cultivation cycle *t* (Equation 5.27)	tCO_2e/acre

Equation 5.27. Nitrous Oxide Emissions from Biomass Burning

$$\boldsymbol{\overline{N2O\_bb_{s,t}} = \frac{\sum_{C}\left(MB_{c,s,t} \times CF_c \times EF_{c,N2O}\right)}{A_s} \times \frac{1}{10^6} \times GWP_{N2O}}$$

Where,			Units
$\overline{N2O\_bb_{s,t}}$	=	Average nitrous oxide emissions due to biomass burning in stratum *s* in cultivation cycle *t*	tCO_2e/acre
$MB_{c,s,t}$	=	Mass of agricultural residues of type *c* burned in stratum *s* in cultivation cycle *t*	kg
CF_c	=	Combustion factor for agricultural residue type *c*, based on proportion of pre-fire fuel biomass consumed	
$EF_{c,N2O}$	=	Nitrous oxide emission factor for the burning of agricultural residue type *c*	g N_2O/kg dm burnt
A_s	=	Area of stratum *s*	acres
$\frac{1}{10^6}$	=	Conversion factor	g/t
GWP_{N2O}	=	Global warming potential for N_2O (Table 5.1)	tCO_2e/tN_2O

5.4.3 Carbon Dioxide Emissions

The only quantified source of non-reversible carbon dioxide emissions in a soil enrichment project is the combustion of fossil fuels used in equipment (Equation 5.28). These emissions are calculated based on the total quantity of fuel used for each type of equipment and fuel. Where projects can show that the total CO_2 emissions from fossil fuels are *de minimis* (i.e., less than 5% of total baseline emissions for that reporting period), the project developer may propose an alternative estimation approach. The verifier shall confirm that such an approach is reasonable and conservative.

In addition, if the project developer can show that the fossil fuel emissions in the project scenario should be expected to either remain the same or decline in relation to the baseline, this source may be excluded.

Equation 5.28. Carbon Dioxide Emission Reductions from Fossil Fuels

$$\overline{\boldsymbol{\Delta CO2\_NR_{s,t}}} = \overline{\boldsymbol{CO2\_NR_{bsl,s,t}}} - \overline{\boldsymbol{CO2\_NR_{pr,s,t}}}$$

Where,

			Units
$\overline{\Delta CO2\_NR_{s,t}}$	=	Average carbon dioxide emissions from fossil fuel use in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$\overline{CO2\_NR_{bsl,s,t}}$	=	Average baseline carbon dioxide emissions from fossil fuel use in stratum *s* during cultivation cycle *t* (Equation 5.29)	tCO_2e/acre
$\overline{CO2\_NR_{pr,s,t}}$	=	Average project carbon dioxide emissions from fossil fuel use in stratum *s* during cultivation cycle *t* (Equation 5.29)	tCO_2e/acre

Equation 5.29. Carbon Dioxide Emissions from Fossil Fuels

$$\overline{\boldsymbol{CO2\_NR_{s,t}}} = \frac{\sum_j \left(\boldsymbol{FFC_{j,s,t}} \times \boldsymbol{EF_{CO2,j}}\right)}{\boldsymbol{A_s}}$$

Where,

			Units
$\overline{CO2\_NR_{s,t}}$	=	Average carbon dioxide emissions from fossil fuel use in stratum *s* during cultivation cycle *t*	tCO_2e/acre
$FFC_{j,s,t}$	=	Consumption of fossil fuel in vehicle/equipment type *j* for stratum *s* in cultivation cycle *t*	gal
$EF_{CO2,j}$	=	Emission factor for the type of fossil fuel *j* combusted	tCO_2e/gal
j	=	Types of fossil fuels	
A_s	=	Area of stratum *s*	acres

5.5 Emissions from Leakage

Where yield of a given crop drops on project fields, as a result of project activities, it is considered market-shifting ‘leakage’, or a secondary effect of the offset project. The principle of leakage suggests that in such circumstances there will be a proportionate increase in yield elsewhere, as the market reacts to the drop in supply, and so the associated GHG impacts are simply shifted, not eliminated – they ‘leak’ outside of the project boundary. In such circumstances it is often seen as best practice to require the project to artificially increase their yield data, so that they account for GHG emissions that would otherwise leak outside of the project.

As discussed in Appendix C, soil enrichment projects are unlikely to result in market-shifting leakage so long as the project area remains in commodity crop production. Moreover, research indicates that the project activities should not have long-term negative impacts on crop yields. Thus, the risk of market-shifting leakage is low for soil enrichment projects. However, this protocol seeks to provide additional protection from specific scenarios where leakage would be most likely, if it were to occur at all:

Scenario 1: Displacement of livestock outside of the project area
Scenario 2: Sustained decline in harvested yield for cash crops grown in the project area

These scenarios are only relevant for fields which employ livestock grazing and/or produce cash crop harvests. Project activities on other fields are categorically not expected to result in emissions leakage.

5.5.1 Accounting for Leakage from Livestock Displacement

Livestock populations must be monitored in the project scenario in order to quantify project emissions from grazing activities (the calculation of CH_4 from enteric fermentation and manure deposition, as well as the calculation of N_2O from manure deposition). In order to account for potential leakage, the level of grazing activity, as a function of both population and grazing time, must be monitored. To avoid crediting for emission reductions which correspond with emissions leakage, the level of grazing activity used to quantify project emissions may not be lower than the average level of grazing activity in the historic baseline period. Thus, if livestock displacement occurs, those emissions will continue to be counted in the project scenario as emissions leakage.

For projects using the default equations, this is monitored as animal grazing days (or AGD). The average AGD for the historical baseline period shall represent the minimum bound for the value of AGD used when calculating the *project scenario* emissions in Equation 5.11b, Equation 5.13b, Equation 5.23, and Equation 5.24.

For projects employing models to estimate grazing emissions, the inputs will include population and some form of time (either days or hours). These will be averaged for the historical baseline period in units appropriate to the model being employed, and used when calculating the *project scenario* emissions as represented in Equation 5.11a, Equation 5.13a, and Equation 5.18a.

5.5.2 Accounting for Leakage from Yield Reduction of Cash Crops

If cash crops grown within the project area experience significant, prolonged yield decline, the market could shift the related emissions through increased production outside of the project area. In order to mitigate this type of leakage, it is important to monitor the yield of cash crops produced in the project area. Each major category of cash crop shall be assessed separately (e.g., corn, wheat, rice, etc.).

For major crops in the U.S. which are supported by crop insurance programs, farmers report a long-term yield metric known as the Actual Production History (APH). These are also the crops with the greatest risk of resulting in market-shifting leakage due to yield decline within the project area. APH is a useful metric for the assessment of yield over time because it is calculated according to established government methods, and it must be reported to the government in order to receive crop insurance. This results in transparency and verifiability.

In order to assess the risk of market-shifting leakage within the project, the project developer shall report the average APH across all acres of each crop within each cultivation cycle. If, for any given crop, in a given cultivation cycle, the difference between the project area APH and the regional average APH for the same crop, calculated as a “yield ratio,” declines by more than 5 percentage points, as compared to the average yield ratio for that crop during the historical baseline period, all emission reductions (both reversible and non-reversible) from strata containing fields producing that crop shall be discounted by that number of percentage points exceeding the threshold until a cultivation cycle where the difference between the project APH and the regional average APH for that crop no longer exceeds this threshold. The reduction is proportional to the area of the stratum growing a particular crop. The regional average APH used for this comparison should be the smallest geographic or political unit which encompasses the project fields growing crop c. For example, a project which includes only corn fields in Iowa may compare the project APH for corn against the Iowa statewide APH for corn. A project in multiple states may compare against an average of statewide APH values. A project at a smaller scale may be able to apply the local agricultural statistics district (ASD) average APH.

Equation 5.30. Deduction for Leakage due to Yield Decline in Cash Crops

$$\boldsymbol{LE_{s,t} = MAX\left(0, \sum_{c}\left(\overline{YR_{bsl,s,c}} - YR_{s,c,t}\right) \times \left(A_{s,c,t}\Big/\textstyle\sum_{c} A_{s,c,t}\right) - 0.05\right)}$$

Where,			Units
$LE_{s,t}$	=	Leakage deduction for crop *c* in stratum *s* during cultivation cycle *t*	
$\overline{YR_{bsl,s,c}}$	=	Average yield ratio for crop *c* of stratum *s* during the historical baseline period	
$YR_{s,c,t}$	=	Project-specific yield ratio for crop *c* in stratum *s* during cultivation cycle *t*	
$A_{s,c,t}$	=	Area of fields growing crop *c* in stratum *s* during cultivation cycle *t*	acres

Equation 5.31. Project-Specific Crop Yield Ratio in the Project Scenario

$$\boldsymbol{YR_{s,c,t} = \frac{\overline{APH_{s,c,t}}}{\overline{APH_{RA,c,t}}}}$$

Where,			Units
$YR_{bsl,s,c}$	=	Project-specific yield ratio for crop *c* in stratum *s* during cultivation cycle *t*	
$\overline{APH_{RA,c,t}}$	=	Regional average APH for crop *c* during cultivation cycle *t*	Bu/ac
$\overline{APH_{s,c,t}}$	=	Average APH reported by fields growing crop *c* in stratum *s* during cultivation cycle *t*	Bu/ac

Equation 5.32. Average Yield Ratio During the Historical Baseline Period

$$\boldsymbol{\overline{YR_{bsl,s,c}} = \frac{\sum_{hy} \overline{APH_{s,c,hy}}}{\sum_{hy} \overline{APH_{RA,c,hy}}}}$$

Where,			Units
$\overline{YR_{bsl,s,c}}$	=	Average yield ratio for crop *c* of stratum *s* during the historical baseline period	
$\overline{APH_{RA,c,hy}}$	=	Regional average APH for crop *c* during cultivation cycle *hy* of the historical baseline period	Bu/ac
$\overline{APH_{s,c,hy}}$	=	Average APH reported by fields growing crop *c* in stratum *s* during cultivation cycle *hy* of the historical baseline period	Bu/ac

Equation 5.33. Average Annual Crop Yield During the Historical Baseline Period

$$\overline{\boldsymbol{APH}_{\boldsymbol{s,c,hy}}} = \frac{\sum_{f}\left(\boldsymbol{APH}_{\boldsymbol{f,s,c,hy}} \times \boldsymbol{A}_{\boldsymbol{f,s,c,hy}}\right)}{\sum_{f} \boldsymbol{A}_{\boldsymbol{f,s,c,hy}}}$$

Where,			Units
$\overline{APH_{s,c,hy}}$	=	Average APH reported by fields in stratum *s*, growing crop *c*, during cultivation cycle h*y* of the historical baseline period	Bu/ac
$APH_{f,s,c,hy}$	=	APH for field *f* in stratum *s* growing crop *c* during cultivation cycle *hy*	Bu/ac
$A_{f,s,c,hy}$	=	Area of field *f* in stratum *s* growing crop *c* during historical cultivation cycle *hy*	acres

6 Project Monitoring

The Reserve requires a Monitoring Plan to be established for all monitoring and reporting activities associated with the project. The Monitoring Plan will serve as the basis for verifiers to confirm that the monitoring and reporting requirements in this section and Section 7 have been and will continue to be met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.3 will be collected and recorded.

At a minimum, the Monitoring Plan shall include the following details:

1. A general description of the project, including number of fields and location information
    a. The project monitoring plan will be a private document, so field location information can be specific
2. A description of practice changes implemented
3. A description of how the eligibility requirements are met
    a. the Monitoring Plan must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test (Section 3.4.2) and maintains regulatory compliance (Section 3.6).
    b. details on the baseline determination
    c. a description of how permanence requirements will be met
4. frequency of data acquisition
    a. The frequency of data monitoring will depend on both the nature of the metric being monitored (e.g., fertilizer applications, crop type) as well as the method employed for data collection (e.g., paper logs, smartphone applications, machine data, etc.). At a minimum, the data required for quantification of soil enrichment projects shall be monitored and recorded (or documented, as appropriate) for each cultivation cycle.
5. a record keeping plan (see Section 7.1 for minimum record keeping requirements)
6. the frequency of instrument cleaning, inspection, field check, and calibration activities (if relevant)
7. the role of individuals performing each specific monitoring activity
8. QA/QC provisions to ensure that data acquisition and meter calibration are carried out consistently and with precision.
    a. Project developers are responsible for monitoring the performance of the project and ensuring that the operation of all project-related equipment is consistent with the manufacturer's recommendations.
    b.
9. Modeling plan, if applicable
    a. The project monitoring plan will identify the model(s) selected initially and document analysis and results demonstrating validation of the model(s). Model validation datasets will be archived to permit periodic application to calculate model structural uncertainty. The modeling plan will detail all required model input parameters and specify the baseline schedule of agricultural management activities for each sample unit.

10. A description of each monitoring task to be undertaken, and the technical requirements therein
11. Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology)
    - At a minimum, soil enrichment projects must monitor the data listed in Table 3.1. However, depending on the practices adopted and the model selected, additional data or parameters may be required to be monitored. Guidance for monitoring of SOC through direct sampling and testing is provided in Section 6.4.
12. Data to be collected and data collection techniques and sample designs for directly-sampled parameters
13. Data archiving procedures
14. Roles, responsibilities, and capacity of monitoring team and management

Finally,

The Reserve will make available a Monitoring Plan template that includes sections for all required information. Use of the template is not required, but is strongly recommended.

6.1 Monitoring Ongoing Eligibility and Permanence

To maintain eligibility on an ongoing basis, soil enrichment projects must demonstrate that the project area continues to meet the requirements of Section 2 during the reporting period. This includes monitoring of land use, which may be evidenced through a site visit or via remote sensing. Monitoring for the permanence of SOC stocks involves assessment of disturbance of the soil itself. Permanence of SOC stocks may be threatened by discrete disturbance events, such as catastrophic erosion due to flooding, or by long term management changes.

Monitoring during the crediting period that meets the requirements of this protocol for the quantification of emission reduction is sufficient for the identification of potential reversals. Monitoring during the permanence period should be capable of identifying the following potential sources of reversals:

- Land use change
- The presence or absence of tillage
- Extended fallow periods
- Extensive areas of continuously exposed ground

6.2 Monitoring Grazing

For each reporting period, Project Owners must provide both a quantitative and qualitative accounting of grazing activities for the reporting period. In terms of quantitative data, projects must document the type of livestock being grazed and the total animal grazing days for each type (Box 5.3). The livestock shall be categorized according to the categories in the *Soil Enrichment Project Parameters* spreadsheet[20]. These data are used for the parameter AGD_l in Equation 5.12. The frequency of monitoring and the form of the documentation is not prescribed by this protocol. In terms of qualitative reporting, project developers shall include in their monitoring report a description of grazing activity for the reporting period and whether this conforms to the administrative mechanism in place to guard against overgrazing. Written confirmation from the entity or entities providing oversight with respect to this administrative mechanism should be provided to the verifier that no overgrazing has occurred during the

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[20] Available at: http://www.climateactionreserve.org/how/protocols/grassland/.

verification period. The verifier shall use professional judgment to confirm with reasonable assurance that the quantification of project emissions from grazing is conservative, that effective monitoring of grazing has been maintained in accordance with this administrative overgrazing mechanism, and that no overgrazing has been detected using this administrative mechanism.

Examples of documentation that may suffice to demonstrate the quantitative grazing monitoring requirements may include (this list is not comprehensive nor is it intended to define sufficiency of documentation):

- Grazing logs (kept daily, weekly, or monthly) that specify the animal categories, populations, and grazing locations
- Animal purchase and sale records, assuming all animals are grazed on the project area
- Grazing management plan, assuming maximum allowable grazing activity

6.3 Monitoring Project Emission Sources

For fossil fuel emissions (Equation 5.28), if the Project Owner can demonstrate that the total value of $CO2\_NR_{s,t}$ is reasonably expected to be *de minimis* (i.e., less than the relevant materiality threshold), these emissions may be estimated through a conservative method proposed by the Project Owner and deemed acceptable by the verifier. If not required for the approved alternative method, the monitoring of fossil fuels as described in this section is not required.

Otherwise, for each reporting period, the Project Owner must provide documentation for the following parameters used for the quantification of project emissions:

- Total acres burned and cause(s) of fire(s)
- Animal grazing days by livestock category
- Mass of fertilizer applied (other than manure from grazing), by type
- Nitrogen content of fertilizer applied, by type
- Purpose, type, and quantity of fossil fuels used (e.g., tractor, diesel, 100 gallons)

For project fields that employ fertilizer additions, it is strongly encouraged that the fertilizer application on those fields is guided by a nutrient management plan. Nutrient management plans should consider the principles contained in NRCS Conservation Practice Standard 590 for Nutrient Management[21]. Where a project also incorporates irrigation, grazing, and/or the use of nitrogen fixing crops, such activities should be taken into account in developing any nutrient management plan for the project. Development of and adherence to a nutrient management plan is not required, but is strongly recommended.

6.4 Soil Sampling and Testing Guidance

Direct measurement of soil organic carbon levels must be performed via soil sampling to establish values to be used as the basis for baseline modeling and, as applicable, project modeling, as well as for ongoing updates to sampled soil organic carbon levels required at least every five years. Project owners must provide documentation describing the soil sampling and laboratory analysis methods employed to estimate soil carbon stocks. While this protocol does not require specific soil sampling and laboratory analysis methods to be used, it does require that a set of minimum standards be met, as outlined in the following sections, and that statistical uncertainty associated with sampling be quantified, as described in Section 5.2, to moderate the

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[21] Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046896.pdf.

crediting outcomes derived from soil organic carbon stocks. Confidence deductions are applied to estimated changes in carbon stocks at increasing rates as statistical uncertainty, including uncertainty associated with sampling, increases.

Although specific methods are not required under this protocol, the Reserve has developed a companion document—the Soil Enrichment Project Development Handbook[22]—that provides further detail and discussion of the various options for satisfying the requirements of this section.

6.4.1 Sample Design and Soil Collection

Since the approach to sampling soil organic carbon levels will vary from project to project, Project Owners must describe their sampling approach in the Monitoring Plan. Regardless of the exact approach used, all projects must adhere to the minimum standards identified in Table 6.1. The application of this protocol will often result in the use of a multi-stage sample design (i.e., two or more stages), at a minimum incorporating the primary sample unit and sample points (e.g., aggregate soil cores) within sample units as the secondary unit. This approach may be expanded to incorporate a range of other sampling approaches to improve efficiency, e.g., pre- or post-stratification, variable probability sampling (e.g., probability proportional to area), etc.

For all directly-sampled parameters, the project Monitoring Plan will clearly delineate spatially the sample population and specify sampling intensities, selection of sample units and, as applicable, locations of sample points within sample units (and control sites).

In addition to the minimum standards outlined in Table 6.1, Project Owners are advised to consider the verification guidance in Section 8.4 associated with verification of soil organic carbon sampling prior to settling on a sample design.

Table 6.1. Minimum Standards for Sampling Soil Organic Carbon

Sample Units and Stratification	▪ All projects must employ either pre- or post-stratification of primary sample units (and any sample stages above the stage based on sample points). ▪ The governing rules for stratification of primary sample units and stratification methodology must be described. The process for updating strata must be described. ▪ Stratification may be based on the following: o Adopted practice change(s) o Soil texture o Soil series o Precipitation (e.g., mean annual) o Temperature (e.g., mean annual) o LRR climate zone o Aridity index o Soil wetness index o Indicator variable for whether the land was flooded o Slope o Aspect ▪ Stratum areas must be provided at verification with maps and tabular outputs.

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[22] The Soil Enrichment Project Development Handbook will be available for download from the Reserve website at: http://www.climateactionreserve.org/how/protocols/soil-enrichment/. This handbook will be updated periodically.

Sample Depth	▪ Minimum of 30cm (sampling may be conducted at deeper layers, if desired) ▪ Projects may only be credited with respect to SOC gains to depths up to or less than the depth of their original baseline sample. If a project seeks to be credited to a depth below their original baseline SOC sample, approval must be given by the Reserve. If soils are sampled below 30 cm, it is advised that they are split into at least two depth increments to distinguish changes in the upper and lower portions of the soil profile. If the model employed by the project is not capable of projecting changes to SOC below 30 cm, samples must be split into at least two depth increments, with the upper portion (30 cm) used for initial modeling. All soil samples must be reviewed during verification of the reporting period in which they were sampled. Data for the lower portion(s) may be retained for potential future use, though actual soil samples may be discarded. If models become capable of projecting changes in SOC at depths below 30 cm in the future, verified data retained from such lower depths can be used to quantify emission reductions, and CRTs may be issued in the first reporting period for which such modeling is available.
Sample location	▪ Geographic locations of intended sampling points must be established prior to sampling. ▪ The location of both the intended sampling point and the actual sampling point must be recorded. ▪ Geotagged photographs should be made available for verification
Site preparation	▪ All organic material (e.g., living plants, crop residue) must be cleared from the soil surface prior to soil sampling.
Sample handling	▪ If multiple cores are composited to create a single sample, these cores must all be from the same depth and be fully homogenized prior to subsampling. ▪ Soils must be shipped within 5 days of collection and should be kept cool until shipping.

6.4.2 Laboratory Analysis

As with soil sampling, the exact methods used to analyze soil samples will vary between projects. Nevertheless, Project Owners must describe in the Monitoring Plan the laboratory analysis methods used to determine soil carbon levels, adhering to the minimum standards outlined in Table 6.2.

Table 6.2. Minimum Standards for Laboratory Analysis of Soil Samples

General Soil Sample Preparation	▪ Soils must be dried within 48 hours of arrival at lab or kept in refrigeration. ▪ Soil aggregates must be broken apart by hand (not by use of mechanical pulverizers or grinders) and soils sieved to < 2mm. All soil carbon analysis should be performed on the fine (< 2mm) fraction only. ▪ If bulk density methods are being used to convert soil carbon concentration to soil carbon stocks, coarse (>2mm fraction) content corrections to bulk density must be made. All soil samples must be reviewed during verification of the reporting period in which they were sampled. Data for the lower portion(s) may be retained for potential future use, though actual soil samples may be discarded.

Analysis Technique	▪ Soil carbon analysis can be performed using either dry combustion techniques or spectroscopic techniques. Unless and until approved by the Reserve at a later date, Loss on Ignition and Walkley-Black methods may not be used under this protocol since they do not provide the necessary accuracy and precision for soil carbon measurements as of the date of protocol adoption. Spectroscopic techniques should only be used for repeat measurements, unless approved by the Reserve. ▪ If using dry combustion to quantify soil organic carbon, any inorganic carbonates must be accounted for using either (1) an acid pretreatment prior to dry combustion analysis or (2) quantification of carbonates using a pressure calcimeter or IR spectroscopy. ▪ Standards and duplicate samples should be run routinely to characterize within-run and between-run precision. ▪ If using spectroscopic methods to quantify soil carbon, the accuracy and precision of the device across the range of geographies and soil types within the project must be accounted for in the uncertainty deduction. This includes any measurement errors related to calibration transfer between different devices: o For each sample point, at least 100 draws will be made from sampling distributions of estimates of soil organic carbon concentration (and potentially bulk density) for the selected device and spectral model. Sampling distributions may be derived from analysis of a validation dataset (of measurements with dry combustion and the spectrometer) or from results published by either the device manufacturer or the scientific community. For example, if (i) the spectral measurements are approximately unbiased, (ii) the standard error of dry combustion is *A* according to replication experiments, and (iii) the standard deviation of errors made by the spectrometer (compared to dry combustion) is *B*, then, assuming independence of errors of dry combustion and the spectrometer, the standard error of the spectrometer is sqrt($B^2 - A^2$).
	Derivation Define errors made by the measurements of dry combustion and a spectrometer: $Dry\_combustion\_estimate = true + error\_dc$ $Spectral\_estimate = true + error\_spec$ We never observe the truth; we can only estimate the differences between our two measurements: $Spectral\_estimate - dry\_combustion\_estimate = error\_spec - error\_dc,$ the variance of which estimates $Var(error\_dc) + Var(error\_spec) - 2\,Cov(error\_dc, error\_spec).$ Assuming that *error_dc* and *error_spec* are independent (which eliminates the covariance term), we can estimate variance of the spectrometer's estimate as: $Var(Spectral\_estimate) = Var(Spectral\_estimate - dry\_combustion\_estimate) - Var(dry\_combustion\_estimate).$ For example, if the typical standard error from dry combustion is 0.1% SOC and the standard deviation of *Spectral_estimate* – *dry_combustion_estimate* is 0.2 %SOC, then *Var(Spectral_estimate)* = $(0.2\ \%SOC)^2 - (0.1\ \%SOC)^2 = 0.03\ (\%SOC)^2$, so the standard error of a spectral measurement is *sqrt(Var(Spectral_estimate))* = *sqrt*$(0.03\ (\%SOC)^2) = 0.173\ \%SOC$.

6.5 Modeling Guidance

The methodology does not mandate the use of any specific model. Models used to estimate stock change/emissions may be empirical or process-based, and must meet the following conditions:

1. Publicly-available;
2. Peer-reviewed by a recognized, competent organization, or an appropriate peer review group; [23]
3. Able to support repeating the project model simulations. This includes clear versioning of the model use in the project, stable software support of that version, as well as fully reported sources and values for all parameters used with the project version of the model. In the case where multiple sets of parameter values are used in the project, full reporting includes clearly identifying the sources of varying parameter sets as well as how they were applied to estimate stock change/emissions in the project. Acceptable sources include peer-reviewed literature and appropriate expert groups, and must describe the data sets and statistical processes used to set parameter values (i.e., the parameterization or calibration procedure, see guidance described in 5);
4. Incorporate one or more input variables that are monitored ex-post; and,
5. Validated according to the guidance in contained in the external document titled *Model Calibration, Validation, and Verification Guidance for Soil Enrichment Projects*, using the same parameters or sets of parameters applied to estimate SOC/trace gas emissions in the project.[24]

The same model(s) version(s) and parameters/parameter sets must be used in both the project and baseline scenarios. Model input data must be derived following guidance in Table 6.3. Model uncertainty must be quantified following guidance in Appendix D. Models may be recalibrated or revised based on new data, or a new model applied, providing the above requirements are met. Guidance is provided in Section 8.3 on requirements for verification of the proper use of models.

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[23] This may mean that peer-reviewed journal articles have employed the relevant model.

[24] Available for download at: https://www.climateactionreserve.org/protocols/soil-enrichment/.

6.6 Monitoring Parameters

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.3. Where a project is able to choose from various sources, the most accurate data should always be used first, followed by the most conservative option, and where unavailable, alternative options be used.

Notes on the parameters used in Table 6.3

Please note that we continue to work on the parameters to be used with this protocol, and that we are likely to replace a number of the IPCC parameters referenced in Table 6.3 with more U.S.-specific parameters. Please also note that we are likely to list all parameters in an external parameters document, to be published alongside the final protocol.

Table 6.3. Soil Enrichment Project Monitoring Parameters

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
	Regulations	Monitoring of regulations relevant to project activities	Environmental regulations	n/a	Each verification cycle	Information used to: 1) To demonstrate ability to meet the legal requirement test – where regulation would require soil enrichment project activities 2) To demonstrate compliance with associated environmental rules, e.g., criteria pollutant emission standards, health and safety, etc.
	A_s	Area of stratum *s*	Acres	m	Each reporting period	Delineation of the stratum area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points. This value will be updated with each reporting period as fields are added or removed, or stratification is adjusted.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
5.3, 5.9, 5.10a, 5.11a, 514a	$VarA_{s,}$, $VarB_{s,}$, $VarC_{s,}$ etc.	Value of model input variable A, B, C, etc. for stratum *s* in cultivation cycle *t*	Units unspecified	o	Each reporting period	Biogeochemical model input variables. See Section 3.4.1.1for data requirements. Relevant for both the baseline and project scenarios.
5.29	$EF_{CO2,j}$	Emission factor for the type of fossil fuel *j* combusted	tCO_2e/gal	r	Each reporting period	For gasoline EF_{CO2}=10.637 kg CO_2 per gallon. For diesel EF_{CO2}=10.925 kg CO_2 per gallon. *Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 Chapter 3 Table 3.3.1. Assumes 4-stroke gasoline engine for gasoline combustion and default values for energy content of 47.1 GJ/t and 45.66 GJ/t for gasoline and diesel respectively (IEA. 2004. Energy Statistics Manual).*
5.29	$FFC_{,j,i,t}$	Consumption of fossil fuel type *j* for sample unit *i* in year *t*	gallons	o	Each reporting period	Fossil fuel consumption can be monitored, or the amount of fossil fuel combusted can be estimated using fuel efficiency of the vehicle and the appropriate unit of use for the selected fuel efficiency. Peer-reviewed published data may be used to determine fuel efficiency. For example, fuel efficiency factors may be obtained from the 2019 Refinement to IPCC 2006 Volume 2 Chapter 3
5.9, 5.11a, 5.11b, 5.13a, 513b	GWP_{CH4}	Global warming potential for CH_4	tCO_2e/tCH_4	r	Each reporting period	Unless otherwise directed by the Reserve, this protocol requires that CH_4 must be converted using the 100-year global warming potential derived from the IPCC Fourth Assessment Report.
5.13	$PEF_{ent,l}$	Project emission factor for enteric methane emissions from livestock category *l* in the project state	kg CH_4/(head * day)	r	Each reporting period	Referenced for the project site state based on default tables in the project parameters spreadsheet document, *Soil Enrichment Project Parameters*, available at: http://www.climateactionreserve.org/how/protocols/soil-enrichment/

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
5.11b	VS_l	Volatile solids excreted by grazing animals in category *l*	kg VS/animal/day	r	Each reporting period	Referenced for the project site state based on default tables in the project parameters spreadsheet available at: http://www.climateactionreserve.org/how/protocols/soil-enrichment/
5.15, 5.27,	CF_c	Combustion factor for agricultural residue type *c*	Proportion of pre-fire fuel biomass consumed	r	Once	Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.6. The combustion factor is selected based on the agricultural residue type burned
5.15	$EF_{c,CH4}$	Methane emission factor for the burning of agricultural residue type *c*	g CH_4/kg dry matter burnt	r	Once	Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.5. The emission factor is selected based on the agricultural residue type burned.
5.18a, 5.20, 5.21, 5.23, 5.24, 5.25	GWP_{N2O}	Global warming potential for N_2O	tCO_2e / tN_2O	r	Each reporting period	Projects must use the 100-year global warming potential derived from the IPCC Assessment Report stipulated in the latest version of the Climate Action Reserve Offset Program Manual, which at the time of release of this protocol was the Fourth Assessment Report.
5.20, 5.25	$EF_{Ndirect}$	Emission factor for direct nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments and crop residues	tN_2O-N/t N applied	r	Once	Value applied = 0.01. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.1. Emission factor applicable to N additions from mineral fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as result of loss of soil carbon
5.21	$Frac_{GASF}$	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NO_x	dimensionless	r	Once	Value applied = 0.1. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
5.21	$Frac_{GASM}$	Fraction of all organic N added to soils that volatilizes as NH_3 and NO_x	dimensionless	r	Once	Value applied = 0.3. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3.
5.21, 5.24	EF_{Nvolat}	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces	tN_2O-N /(t NH3-N + NOx-N volatilized)	r	Once	Value applied = 0.01. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3.
5.21	$Frac_{LEACH}$	Fraction of N added (synthetic or organic) to soils that is lost through leaching and runoff, in regions where leaching and runoff occurs	dimensionless	r	Once	Value applied = 0.3. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
5.21, 5.24	EF_{Nleach}	Emission factor for nitrous oxide emissions from leaching and runoff	tN_2O-N / t N leached and runoff	r	Once	Value applied = 0.0075. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3.
5.23	$EF_{N2O,md,l}$	Emission factor for nitrous oxide from manure and urine deposited on soils by livestock type	kg N_2O-N/kg N input	r	Each reporting period	The emission factor for nitrous oxide from manure and urine deposited on soils is determined based on livestock type. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.21
5.24	N_ex_l	Nitrogen excretion of livestock type	kg N deposited/(t livestock mass * day)	r	Each reporting period	Referenced for the project site state based on default tables in the project parameters spreadsheet.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
5.24	$Frac_{GASMD,l}$	Fraction of N in manure and urine deposited on soils by livestock type that volatilizes as NH_3 and NO_x	dimensionless	r	Each reporting period	The fraction of N in manure and urine deposited on soils that volatilizes as NH_3 and NO_x is determined based on livestock type. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 Table 10.22
5.24	$Frac_{LEACHMD}$	Fraction of N in manure and urine deposited on soils that is lost through leaching and runoff, in regions where leaching and runoff occurs	dimensionless	r	Once	Value applied = 0.30. Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.3
5.25	$N_{content,g}$	Fraction of N in dry matter for N-fixing species *g*	t N/t dm	r	Each reporting period	The fraction of N in dry matter is determined based on the N-fixing species type. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 11 Table 11.2.
5.27	$EF_{c,N2O}$	Nitrous oxide emission factor for the burning of agricultural residue type *c*	g N_2O/kg dry matter burnt	r	Once	The emission factor is selected based on the agricultural residue type. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 2 Table 2.5.
5.11, 5.13 Box 5.3 5.23 5.24	$AGD_{,l,s,t}$	Grazing days in stratum *s* for each livestock type *l* in year *t*	Number of days	o	Each reporting period	See Section 3.4.1.1 for data requirements.
5.15, 5.27	$MB_{c,i,t}$	Mass of agricultural residues of type *c* burned in the baseline scenario for sample unit *i* in year *t*	Kilograms	r	Each reporting period	Peer-reviewed published data may be used to estimate the aboveground biomass prior to burning. It is conservatively assumed that 100% of aboveground biomass is burned.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
5.20	$M_{SF,s,t}$	Mass of N containing synthetic fertilizer applied for stratum *s* in cultivation cycle *t*	kg fertilizer	o	Each reporting period	See Section 3.4.1.1 for data requirements.
5.20	NC_{SF}	N content of synthetic fertilizer applied	t N/t fertilizer	o	Each reporting period	N content is determined following fertilizer manufacturer's specifications. See box 9.1 for data requirements.
5.20	$M_{OF,i,t}$	Mass of baseline N containing organic fertilizer applied for sample unit *i* in year *t*	t fertilizer	o	Each reporting period	See Section 3.4.1.1 for data requirements.
5.20	NC_{OF}	N content of baseline organic fertilizer applied	t N/t fertilizer	r	Once	Peer-reviewed published data may be used. For example, default manure N contents may be selected from Edmonds et al. (2003) cited in U.S. Environmental Protection Agency. (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. *EPA 430-R-11-005*. Washington, D.C.
5.25	$MB_{g,s,t}$	Annual dry matter, including aboveground and below ground, of N-fixing species *g* returned to soils for stratum *s* at time *t*	t dm	o	Each reporting period	See Section 3.4.1.1 for data requirements.

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Description
Box 5.1	$\overline{\Delta G_t}$ and $\overline{G_t}$	Average emission reductions and average emissions, respectively from pool or source G in cultivation cycle t.	tCO_2e/ac	m or c	Each reporting period	Calculated from modeled or measured values in the project area. The average emission reductions from pool or source G, or from changes in the stock of pool G, at time t are estimated using unbiased statistical approaches, such as from: Cochran, W.G. (1977). Sampling Techniques: 3d Ed. New York: Wiley. It is understood that application of this methodology may employ sample units of unequal sizes, which would necessitate proper weighting of samples in deriving averages. A range of sample designs (e.g., simple random samples, stratified samples, variable probability samples, multi-stage samples) may be employed.

7 Reporting Parameters

This section provides requirements and guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. Project developers must submit verified emission reduction reports to the Reserve for every reporting period.

7.1 Project Documentation

Project developers must provide the following documentation to the Reserve in order to list a soil enrichment project:

a) Project Submittal form
b) Project map (providing a general overview of where project fields are located, accurate at least to the county level; public)
c) Project map (detailed spatial file in .KML format with precise location of participating fields; not public)

Project developers must provide the following documentation each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions:

- Project maps (updated general overview map and .KML file, if changed from listing and/or previous reporting period)
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Monitoring plan (initial reporting period)
- Monitoring report (all reporting periods)
- Contract(s) for ownership of emission reductions (where applicable)

Verifiers will provide a verification report, list of findings, and verification statement. The Reserve will coordinate executing of a Project Implementation Agreement during the initial reporting period, and Project Implementation Agreement Amendments during subsequent reporting periods. At a minimum, the above project documentation (except for the detailed project map) will be available to the public via the Reserve's online registry. Further disclosure and other documentation may be made available on a voluntary basis through the Reserve. Project developers may seek Reserve approval for redacting sensitive business information contained in any documents that are to be posted publicly. Project submittal forms can be found at http://www.climateactionreserve.org/how/program/documents/.

7.2 Defining the Reporting Period

The reporting period is the period of time over which GHG emission reductions from project activities are quantified. The typical reporting period under this protocol is one complete cultivation cycle. The cultivation cycle may be defined differently for annual crops, perennial crops, and perennial pasture, but should align with the end of one growing season and the beginning of another. For the purposes of this protocol, a cultivation cycle is generally defined as the period between the first day after harvest of the last crop on a field and the last day of harvest of the last crop on a field during the reporting period (Figure 7.1). However, this definition will be adjusted in several different scenarios.

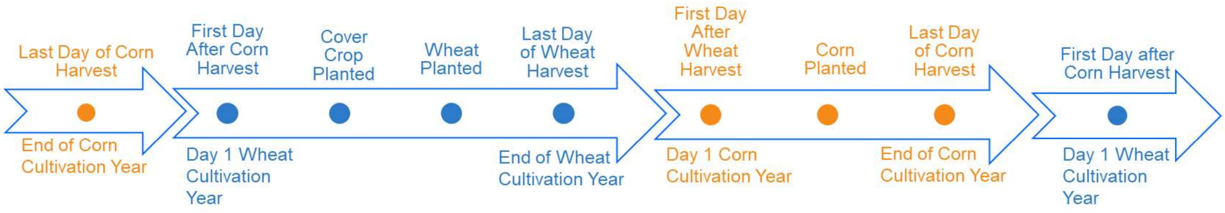
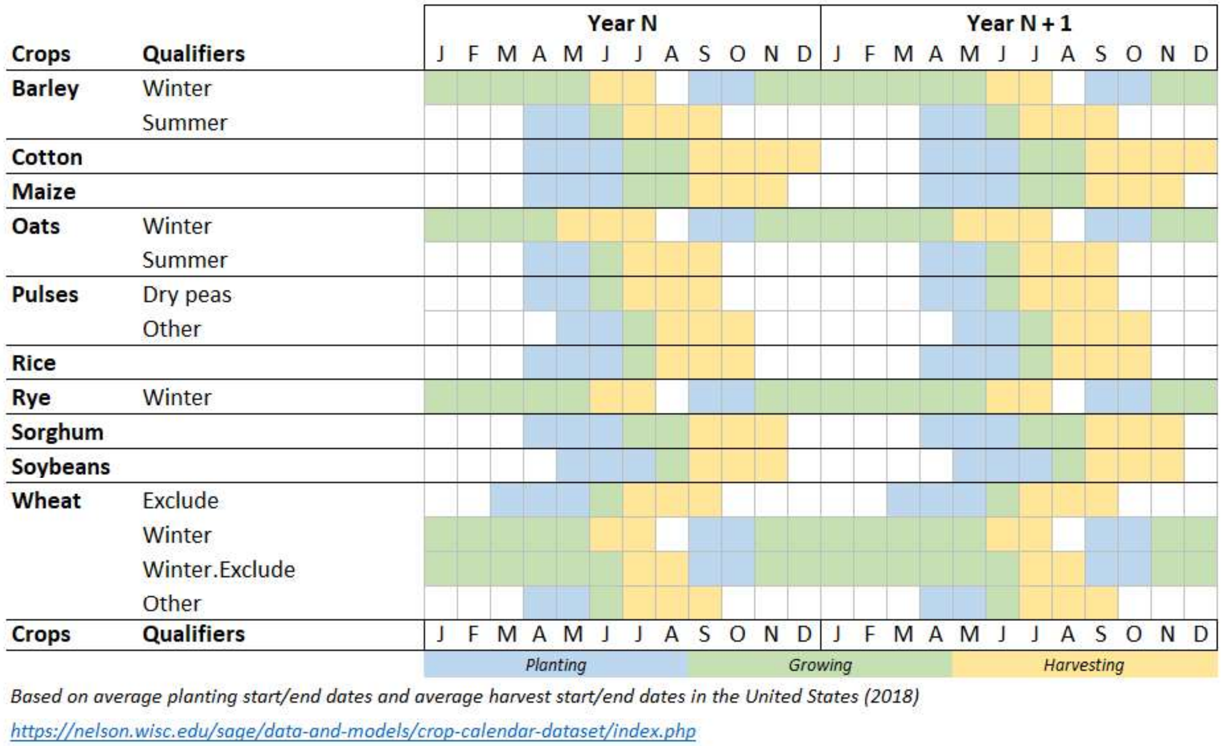


Figure 7.1. Example of a Typical Cultivation Cycle

For fields with perennial cropping systems (including grazing), or systems where there is not a clear harvest event between seasons (e.g., cash crop seeded directly into a living cover crop), the project developer shall document and/or justify the date chosen to represent the end of one growing season and the beginning of the another (e.g., planting date). Figure 7.2 below, illustrates the variability in agronomic cycles for various crops throughout the year, demonstrating why flexibility is required for soil enrichment projects.

- A cultivation cycle may be greater or less than a calendar year, and may include multiple growing seasons, including cash crops, cover crops, and pasture
- For perennial crops with one or more harvests during a growing season, the last harvest will generally define the cultivation cycle
- For perennial crops without harvests or perennial pasture systems, the cultivation cycle may be defined by the project developer in a way intended to align with the annual cycle of growth on the field
- For cultivation cycles which begin following a period of pasture, the cultivation cycle may begin with field preparation for crop production
- Where inter-seeding is practiced (through companion cropping, relay cropping, planting cash crops into live cover crops, or planting cover crops into live cash crops), the cultivation cycle may be defined by the project developer
- The length of the cultivation cycle may vary from year to year, depending on weather and the overall crop and management rotation schedule



		Year N												Year N + 1											
Crops	**Qualifiers**	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Barley	Winter	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩
	Summer				🟦	🟦	🟩	🟨	🟨	🟨							🟦	🟦	🟩	🟨	🟨	🟨			
Cotton					🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨	🟨				🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨	🟨
Maize					🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨					🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨	
Oats	Winter	🟩	🟩	🟩	🟩	🟨	🟨	🟨		🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨		🟦	🟦	🟩	🟩
	Summer				🟦	🟦	🟩	🟨	🟨	🟨							🟦	🟦	🟩	🟨	🟨	🟨			
Pulses	Dry peas				🟦	🟦	🟩	🟨	🟨	🟨							🟦	🟦	🟩	🟨	🟨	🟨			
	Other					🟦	🟦	🟩	🟨	🟨	🟨							🟦	🟦	🟩	🟨	🟨	🟨		
Rice					🟦	🟦	🟦	🟩	🟨	🟨	🟨						🟦	🟦	🟦	🟩	🟨	🟨	🟨		
Rye	Winter	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩
Sorghum					🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨					🟦	🟦	🟦	🟩	🟩	🟨	🟨	🟨	
Soybeans						🟦	🟦	🟦	🟩	🟨	🟨	🟨						🟦	🟦	🟦	🟩	🟨	🟨	🟨	
Wheat	Exclude			🟦	🟦	🟦	🟩	🟨	🟨	🟨						🟦	🟦	🟦	🟩	🟨	🟨	🟨			
	Winter	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨		🟦	🟦	🟩	🟩
	Winter.Exclude	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟦	🟦	🟩	🟩
	Other				🟦	🟦	🟩	🟨	🟨	🟨							🟦	🟦	🟩	🟨	🟨	🟨			
Crops	**Qualifiers**	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

🟦 *Planting* 🟩 *Growing* 🟨 *Harvesting*

Based on average planting start/end dates and average harvest start/end dates in the United States (2018)

https://nelson.wisc.edu/sage/data-and-models/crop-calendar-dataset/index.php

Figure 7.2. Illustration of the Range of Dates for Various Crops in the U.S.

When a project comprises multiple eligible crop fields, the reporting period in a given year starts on the earliest date that a field being submitted for credits begins its eligible cultivation cycle, and the reporting period ends on the latest date that a field being submitted for credits ends its cultivation cycle. This will mean that a project may experience overlapping reporting periods (Figure 7.3), i.e., a reporting period may end in November of a given year, but if a winter crop is grown on a field submitted to the project for crediting in the next cultivation cycle, the subsequent project reporting period may actually begin that same November, potentially prior to the end of the last reporting period.

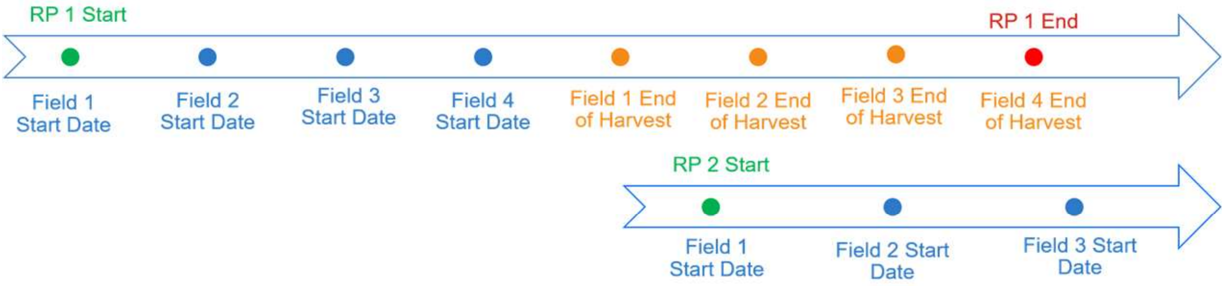


Figure 7.3. Example of Overlapping Reporting Periods for a Project with Multiple Eligible Crop Fields

Despite this, there will be no risk of double issuance of emission reductions, for several reasons:

- Quantification of emission reductions occurs on a field by field basis, based on the cultivation cycle of the given field

- Fields can only be registered to one project at any given point in time, therefore fields can only have emission reductions issued to one project for any given reporting period
- Field reporting periods cannot overlap, because they are defined by the field's cultivation cycle. The new cultivation cycle will only start once the previous crop harvest *on that field* has concluded

Although reporting periods will typically comprise only one cultivation cycle, the initial reporting period may comprise either one or two cultivation cycles. For projects with multiple eligible crop fields and an initial reporting period encompassing two cultivation cycles, the initial reporting period must include two complete cultivation cycles for each eligible crop field (Figure 7.4).

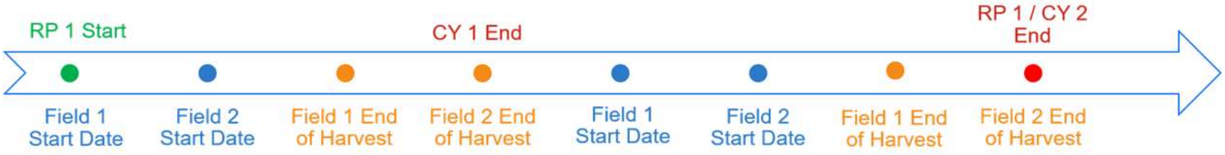


Figure 7.4. Example of Initial Reporting Period Consisting of Two Eligible Crop Cultivation Cycles (CY).

7.3 Reporting Period and Verification Cycle

Project developers must report GHG reductions resulting from project activities during each reporting period. The verification period is the period of time over which project reporting is verified and credits are issued. An individual verification period may comprise no more than five (5) reporting periods. Furthermore, in the event of an avoidable reversal, the verification period may be required to be shortened to fulfill the compensation requirements specified in Section 5.3.2.1. To meet the verification deadline, the project developer must have the required project documentation (see Section 7.1) submitted as soon after the end of each reporting period as possible, as verifiers have 12 months following the end of the reporting period to review the project documentation and submit the verification report and statement. For reporting periods for which the project developer is deferring verification to a future date, a monitoring report must be submitted prior to the required verification deadlines (i.e., 12 months following the end of the reporting period).

7.4 Reporting for Aggregated Projects

Projects which aggregate multiple fields and/or Field Managers are not subject to different reporting requirements from projects which comprise only a single field or Field Manager. As described above, aggregated projects will likely result in overlapping reporting periods at the project level. While the emission reductions are quantified for the project as a whole, the data collection and documentation must be conducted at the field level.

7.5 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. If projects wish to measure initial SOC samples below 30 cm with the hope of being able to be credited for SOC gains below 30 cm at some point in the future, such data and the verification of such data must be retained until the time when resulting emission reductions can be effectively modeled, but the soil samples themselves need not be retained (as described in Section 6.4.1).

This information will not be publicly available, but may be requested by the verifier or the Reserve.

System information the project developer should retain includes:

- All data inputs for the calculation of the project emission reductions, including all required sampled data, as well as the results of emission reduction and sequestration calculations
- All modeling outputs (if applicable)
- Copies of all permits, Notices of Violations (NOVs), and any relevant administrative or legal orders dating back at least 3 years prior to the project start date
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation forms
- All verification records and results
- All maintenance records relevant to the monitoring equipment

8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions associated with the project activity. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities specifically related to soil enrichment projects.

Verification bodies trained to verify soil enrichment projects must be familiar with the following documents:

- Reserve Offset Program Manual
- Climate Action Reserve Verification Program Manual
- Climate Action Reserve Soil Enrichment Protocol (this document)
- Any applicable policy memos and errata and clarifications

The Reserve Offset Program Manual, Verification Program Manual, and project protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

Only ISO-accredited verification bodies trained by the Reserve for this project type are eligible to verify soil enrichment projects. Verification bodies approved under other project protocol types are not permitted to verify soil enrichment projects. Information about verification body accreditation and Reserve project verification training can be found on the Reserve website at http://www.climateactionreserve.org/how/verification/.

8.1 Standard of Verification

The Reserve's standard of verification for soil enrichment projects is the Soil Enrichment Protocol (this document), the Reserve Offset Program Manual, and the Verification Program Manual. To verify a soil enrichment project report, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Sections 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve.

8.2 Monitoring Plan

The Monitoring Plan serves as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. Verification bodies shall confirm that the Monitoring Plan covers all aspects of monitoring and reporting contained in this protocol and specifies how data for all relevant parameters in Table 6.3 are collected and recorded.

8.3 Core Verification Activities

The Soil Enrichment Protocol provides explicit requirements and guidance for quantifying the GHG reductions associated with the soil enrichment project. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of a soil enrichment project, but verification bodies must also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emission sources, sinks, and reservoirs (SSRs)
2. Reviewing GHG management systems and estimation methodologies
3. Verifying emission reduction estimates

Identifying emission sources, sinks, and reservoirs

The verification body reviews for completeness of the sources, sinks, and reservoirs identified for a project, based on the guidance in Section 4.

Reviewing GHG management systems and estimation methodologies

The verification body reviews and assesses the appropriateness of the methodologies and management systems that the soil enrichment project operator uses to gather data and calculate baseline and project emissions.

Verifying emission reduction estimates

The verification body further investigates areas that have the greatest potential for material misstatements and then confirms whether or not material misstatements have occurred. This involves site visits to the project field (or fields if the project includes multiple fields) to ensure the systems on the ground correspond to and are consistent with data provided to the verification body. In addition, the verification body recalculates a representative sample of the performance or emissions data for comparison with data reported by the project developer in order to double-check the calculations of GHG emission reductions.

8.3.1 Verifying Proper Use of Models

Guidance for the verification of the proper use of models is contained in *Model Calibration, Validation, and Verification Guidance for Soil Enrichment Projects*.[25]

Each verification team must demonstrate, to the Reserve's satisfaction, that they include a team member in each given reporting period that is sufficiently knowledgeable regarding the use of the particular model used to quantify emission reductions in that reporting period (if any). Verifiers will be required to confirm the requirements of *Model Calibration, Validation, and Verification Guidance for Soil Enrichment Projects* are met.

If the project employs the use of a third-party expert to undertake validation, parameterization, calibration, and/or running a biogeochemical model in a given reporting period, then there will be no need for the verification team to include an expert in the use of such model or to independently verify such activities have been done appropriately, provided the verification team: confirms that the use of such third-party has been approved by the Reserve, that the party in question has the requisite expertise, that all requisite steps as set out in *Model Calibration, Validation, and Verification Guidance for Soil Enrichment Projects* have been followed, and provided the expert provides the verification team with a sensitivity analysis regarding the requisite data inputs for the given model.

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[25] Available for download at: https://www.climateactionreserve.org/protocols/soil-enrichment. Ensure that you are referring to the most current version of this guidance document for the relevant version of the SEP.

In other words, the verifier is simply required to confirm approval from the Reserve, confirm the qualification of the third-party, and confirm the requisite validation steps have been followed, but the verifier does not independently need to run the model themselves to confirm results appear reasonable. The verification team will still be required to confirm the reasonableness of all data input into the given biogeochemical model, following the requirements for baseline modeling in Section 3.4.1.1, and following expert guidance on the sensitivity of the given model to the requisite data inputs.

8.3.2 Verification of Soil Samples

Verifiers need not duplicate the Project Owner's soil samples under this protocol. Verifiers instead should confirm that the requirements detailed in Section 6.4 are carried out appropriately. The Project Owner must demonstrate that the sampling requirements were followed (including separation of samples into depth portions, if applicable, as specified in Section 6.4.1), must provide geotagged photos of the sample locations, and must be able to demonstrate that the sampling technician is qualified and not affiliated with the Project Owner. Similarly, the lab analysis procedures must be demonstrated to have been followed and the laboratory must be demonstrated to be unaffiliated with the Project Owner. During site visits, verifiers may request a demonstration of the soil sample collection procedure.

8.4 Verification of Projects

Guidelines for verification sampling and verification schedules are the same for individual projects (single Field Manager with multiple fields) and aggregated projects (multiple Field Managers and/or multiple fields). This approach allows a consistent application of verification requirements at the project level, regardless of size or number of fields in the project, or whether the projects are combined into an aggregate or not.

In all cases, the verification schedule shall be established by the verification body using a combination of risk-based and random sampling, according to the verification schedule and sampling methodologies outlined in Section 8.4.1. These sampling methodologies establish a minimum, and possible range, of site visit frequencies, as well as guidance on circumstances in which the verification body is encouraged to add fields beyond the minimum number of fields required for site visit and/or desktop verification. The verifier may use professional judgment to determine the number of additional fields and method for selecting fields if a risk-based review indicates a high probability of non-compliance. The verification minimum sampling requirements are mandatory regardless of the mix of entry dates represented by the group of fields in the project (and by the group of growers in the grouped project).

The initial site visit verification schedule for a given year shall be established after the completion of the NOVA/COI process. The schedule should be established as soon as possible after the commencement of verification activities, at a minimum, so as to include both risk-based and random sampling for the selection of site visited fields. This is meant to allow for the project developer and verification body to work together to develop a cost effective and efficient site visit schedule. Specifically, once the sample fields designated for a site visit have been determined, the verification body shall document all fields selected for planned site visit verification and provide a list of fields receiving a visit to the project developer and the Reserve[26]. The project developer shall be responsible for all site visit planning. Following this notification, the project developer shall supply the verification body with all the required

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[26] If the Reserve has indicated staff will be performing oversight on the verification activities, this list must be provided as soon as it is available. If Reserve staff are not performing oversight on the verification activities, this list must be provided with the submittal of the verification report.

documentation to demonstrate field-level conformance to the protocol. When a verification body determines that additional sampling is necessary due to suspected non-compliance, however, a similar level of advance notice may not be possible.

Though significant advance notice of a field's selection for a site visit is required, project developers shall not be given advanced notice of which fields' data will be subject to desktop verification in a given year. A field shall be prepared for desktop verification during every verification period, so long as the field's Monitoring Plan is implemented and up-to-date, the Field Report submitted to the project developer, and all recordkeeping requirements of this protocol are followed.

Regardless of the size of a project, if the project contains any fields that did not pass site visit verification the year before and wish to re-enter the project, those fields must have a full verification with site visit for the subsequent reporting period. These fields must be site visited in addition to the verification sampling methodology and requirements outlined below in Section 8.4.1.

In all cases, when determining the sample size for site visits and desktop verifications, the verification body shall round up to the nearest whole number.

The documentation requirements for performing a site visit verification and desktop verification are the same. A desktop verification is equivalent to a full verification, without the requirement to visit the site. A verification body has the discretion to visit any site in any verification period if the verification body determines that the risks for that field warrant a site visit.

8.4.1 Verification Site Visit Requirements

It is possible that a field in a large project or aggregated project never receives a site visit during its entire crediting period. Therefore, a combination of risk-based and random sampling is a particularly important component of the enforcement mechanism. The sampling methodology for projects shall take place in three steps:

1. Site visit verifications selected via field-level risk assessment: Verifiers shall select fields for site visits first through a risk-based approach. The verifiers' risk evaluation may presume higher risk exists on larger fields or fields that contribute more to the emission reductions, fields that implement a novel practice change, fields that have recently implemented a new practice change from prior reporting periods, or have exhibited challenges during past verifications, etc. Fields representing a minimum of one-half the square root of the total number of fields in the project must be visited. If selection of higher risk fields does not meet this threshold, verifiers proceed to step 2 to select additional fields via random sampling.
2. Additional site visit verifications selected via random sampling: Once the verifier has selected fields for site visits through the risk-based approach, additional fields shall be selected at random. The verification body shall randomly select additional fields until the number of site visits meets a minimum threshold of fields representing at least one half the square root of the total number of fields in the project (or a higher number chosen by the verifier, if appropriate, based on higher project-level risk – see further description below).
3. Desktop verifications selected via random sampling: Verification bodies shall randomly select a sample of fields to undergo a desktop verification equal to the square root of the total number of fields in the project (rounded up to the next whole number). Fields

selected for site visit verifications based on steps 1 and 2 shall not be eligible for selection for desktop verification during that year.

The verification body shall be allowed to vary the number of site visits performed based on levels of perceived project-level risk identified during verification. Specific risks identified during the verification could include fields generating large proportions of the emission reductions of the project, lack of historical records, and/or demonstrated poor communication of project activities and implementation between Field Managers and project developers. If the verifiers and project developer disagree on the number of fields to be visited, they should contact the Reserve.

Each verification report must contain a description of the sampling methodology, number of fields visited, and justification for higher levels of sampling (e.g., due to higher levels of risk).

Once fields have been selected for site visits, verifiers may seek Reserve approval to forgo an actual site visit, if sufficient proxy data exists such that a verifier considers it unnecessary for a member of the verification team to specific set foot at the relevant field. Examples of proxy data that may satisfy a verifier in this regard include where the project developer has engaged an independent third-party with agronomic expertise (such as local NRCS staff and/or local University extension service staff) to instead undertake a site visit, or to complete a signed statement attesting that the things a verifier considered highest risk and for which a site visit would be most useful, have been confirmed by that third-party. In assessing any such request, the Reserve will take into consideration guidance prepared by the ANSI National Accreditation Board (ANAB) on the use of remote site visit verifications, as well as any guidance forthcoming on the use of remote site visit verifications prepared by any other offset registry or program, and any guidance the Reserve itself develops for such activities. All parties should be on notice that Reserve approval will be needed for any such remote site visit activities and that granting of such approval is by no means guaranteed, and that parties should seek such approval from the Reserve as early as possible in order to determine if such approval is likely in any given circumstances.

8.5 Soil Enrichment Verification Items

The following tables provide lists of items that a verification body needs to address while verifying a soil enrichment project. The tables include references to the section in the protocol where requirements are further specified. The tables also identify items for which a verification body is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to soil enrichment projects that must be addressed during verification.

8.5.1 Project Eligibility and CRT Issuance

Table 8.1 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for soil enrichment projects. These requirements determine if a project is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any requirement is not met, either the project may be determined ineligible or the GHG reductions from the reporting period (or subset of the reporting period) may be ineligible for issuance of CRTs, as specified in Sections 2, 3, and 6.

Table 8.1. Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.2	Verify that the project meets the definition of a soil enrichment project a. Evidence provided indicating project was cropland or grassland at the project start date; b. Project does not involve a decrease in woody perennials within the project area; c. Displacement of productive activity in the project area, as measured by the change in annual crop yield and/or livestock [AUMs or stocking rate?] [over any 10-year period during the crediting period], does not exceed 10%	No
2.3	Verify ownership of the reductions by reviewing Attestation of Title, and where relevant, contracts between growers and Project Owner	No
3.2	Verify accuracy of project and field start dates based on operational records	Yes
3.2	Verify that the project has documented and implemented a Monitoring Plan	No
3.3	Verify each field seeking credits in a given reporting period is within its 30-year crediting period	No
3.4.1	Verify that the project meets the performance standard test	No
3.4.2	Confirm execution of the Attestation of Voluntary Implementation form to demonstrate eligibility under the legal requirement test	No
3.4.2	Verify that the project Monitoring Plan contains a mechanism for ascertaining and demonstrating that the project passes the legal requirement test at all times	No
3.5	Verify which option the project has chosen to use to meet the permanence requirements, and verify any evidence as applicable (application of TYA, execution of a PIA, or use of alternative mechanisms)	No
3.5.6	Verify that the project activities comply with applicable laws by reviewing any instances of non-compliance provided by the project developer, by undertaking independent investigations to confirm if any violations exist, and by performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form	Yes
6	Verify that monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations	No

8.5.2 Quantification

Table 8.2 lists the items that verification bodies shall include in their risk assessment and recalculation of the project's GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project's GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

Table 8.2. Quantification Verification Items

Protocol Section	Quantification Item	Apply Professional Judgment?
4	Verify that all SSRs in the GHG Assessment Boundary are accounted for	No
3.4.1.1, 5.1	Verify that the baseline emissions are properly aggregated	No
5	Verify that the project emissions were calculated according to the protocol with the appropriate data	No
5	Verify that the project developer correctly monitored, quantified, and aggregated electricity and fossil fuel use	Yes
5	If default emission factors are not used, verify that project-specific emission factors are based on official source-tested emissions data or are from an accredited source test service provider or Reserve approval has been granted for their use	No
6.4	Verify that stratification and sampling requirements as set out in Section 6.4 were appropriately followed – see Section 8.5.4 for more information on verification of direct measurements	Yes
6.5	Verify that the given biogeochemical model used to model baseline emissions, and optionally reporting period emissions, meets the requirements of this protocol	No
6.5	Verify that the given biogeochemical model used to model baseline emissions, and optionally reporting period emissions, has been properly validated	Yes
3.4.1.2, 6.5	Verify that all biogeochemical model inputs are reasonable, taking into account the baseline evidence hierarchy in Section 3.4.1.2, and guidance provided by an expert in the use of the given biogeochemical model	Yes

8.5.3 Monitoring and Reporting

Verification bodies will review the following items in Table 8.3 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.3. Monitoring and Reporting Verification Items

Protocol Section	Monitoring and Reporting Item	Apply Professional Judgment?
6	Verify that the project Monitoring Plan is sufficiently rigorous to support the requirements of the protocol and proper operation of the project	Yes
6	Verify that appropriate monitoring equipment is in place to meet the requirements of the protocol	No
6	Verify that the individual or team responsible for managing and reporting project activities are qualified to perform this function	Yes
6	Verify that all contractors are qualified for managing and reporting greenhouse gas emissions if relied upon by the project developer. Verify that there is internal oversight to assure the quality of the contractor’s work	Yes
7.5	Verify that all required records have been retained by the project developer	No

8.5.4 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Statement, submitting the necessary documents to the Reserve, and notifying the Reserve of the project's verified status.

9 Glossary of Terms

Accredited verifier	A verification firm, or employee thereof, approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Project activities that are above and beyond “business as usual” operation, exceed the baseline characterization, and are not mandated by regulation.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e., fossil fuel destruction, de-forestation, etc.).
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the Carbon Cycle, as opposed to anthropogenic emissions.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Cropland	Arable and tillage land and agro-forestry systems where vegetation falls below the threshold used for the forest land category (>10% canopy cover).
Direct emissions	GHG emissions from sources that are owned or controlled by the reporting entity.
Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Field Manager	The entity with operational control of agricultural management decisions for a given field(s) in the project area during the relevant reporting period.
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Grassland	Areas dominated by grasses with <10% tree canopy cover, including savannas (i.e., grasslands with scattered trees). Grasslands also include managed rangeland and pastureland that is not considered cropland where the primary land use is grazing, and which may also include grass-dominated systems managed for conservation or recreational purposes.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.
GHG source	A physical unit or process that releases GHG into the atmosphere.

Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
Methane (CH_4)	A potent GHG, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Mobile combustion	Emissions from the transportation of employees, materials, products, and waste resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g., cars, trucks, tractors, dozers, etc.).
N-fixing species	Any plant species that associates with nitrogen-fixing microbes found within nodules formed on the roots, including but not limited to soybeans, alfalfa, and peas.
Organic nitrogen fertilizer	Any organic material containing N, including but not limited to animal manure, compost and sewage sludge. Fertilizers are considered organic if derived from plant and animal parts or residues.
Professional agronomist	Any individual with specialized knowledge, skill, education, experience, or training in crop and/or soil science.
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a GHG project, as identified in Section 2.2 of this protocol.
Sample point	Sample location of undefined area.
Sample unit	Defined area that is selected for measurement and monitoring, such as a field.
Synthetic nitrogen fertilizer	Any synthetic fertilizer (solid, liquid, gaseous) containing nitrogen (N). This may be a single nutrient fertilizer product (only including N), or any other synthetic fertilizer containing N, such as multi–nutrient fertilizers (e.g., N–P–K fertilizers) and 'enhanced–efficiency' N fertilizers (e.g., slow release, controlled release and stabilized N fertilizers). Fertilizers are considered synthetic if derived from inorganic compounds, which are in turn usually derived from by-products of the petroleum industry.
Verification	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve-approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.
Woody perennials	Trees and shrubs having a lifecycle lasting more than two years, not including cultivated annual species with lignified tissues, such as cotton or hemp.

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Appendix A Development of the Performance Standard

This protocol adopts a simplified approach to establishing the additionality of soil enrichment projects. Given the incredible diversity of practice change scenarios, and the myriad variables involved in both farmer decision-making and the estimation of GHG impacts of management practice changes, it would be impossible to develop individual, quantitative performance thresholds based on specific practices. The goal of this protocol – to incentivize multiple practice adoption over time – means that such complex approaches to additionality would be unworkable. Moreover, farmers will not participate in the program with such rigid and complex requirements for entry. Thus, a simplified approach has been adopted, supported by the rationale in this appendix.

The thesis for this approach is summarized as follows:

- Farmers are risk-averse;
- Farmers are motivated by multiple factors, attempting to maximize utility in multiple ways, rather than simply focusing on long-term profit maximization;
- While some practices have seen some measure of adoption in some regions and cropping systems, the overall experience is mixed, without a clear trend towards increasing adoption of soil enrichment practices;
- This protocol goes beyond business-as-usual by ensuring growers receive incentives (carbon credits) only when they adopt practice change, demonstrate measurable GHG impacts of such practice change, and ensure that increases in soil carbon provide atmospheric benefits equivalent to storage maintained for 100 years.

Multiple parties within society are faced by similar broad pressures as those faced by farmers, and multiple parties similarly are thus motivated to pursue utility maximization in a sense broader than a mere focus on economic outcomes. However, individual motivations are rarely directly entwined with the decisions of a commercial enterprise as they are in farming. We contend that for this thesis to effectively demonstrate additionality, it is not necessary to demonstrate that farmers (as individuals) face greater pressures for a broader approach to utility maximization than those faced by other parts of society. It is enough to demonstrate that farmers do face broad and diverse barriers to the adoption of soil enrichment practices, that their personal barriers equate to commercial barriers, and that the mechanisms employed in this protocol present novel means to address such barriers. Incidentally, we will argue in this appendix that farmers do in fact face greater such pressures, than do other parts of society, given the deep interrelationship of their personal and commercial interests.

A.1 Non-Financial Barriers to Adoption of Soil Enrichment Practices

The body of literature on the impact of soil enrichment practices on soil carbon stocks and overall emissions from agricultural operations is growing (Teague, et al., 2016), (Gravuer, Gennet, & Throop, 2019), (IPCC, 2019); however, information needed to project the financial outcome of implementing any one agricultural practice in a given region is lacking due to the emerging nature of soil enrichment practices. Since the 1990s, research on and implementation of soil enrichment practices has expanded. However, for the current generation of farmers, soil enrichment practices were not a part of university agricultural science curricula and are not widely practiced today. This educational gap results in systemic barriers to soil enrichment practices, as this sort of training drives decisions by not only farmers, but also the agronomists who advise them, seed, chemical, and equipment vendors, regulators, and farm lenders. Farmers may not be able to obtain financing if their banker disagrees with their management decisions. They may not even have the chance to make those decisions if those who advise them are not educated in these areas.

While costs and revenues associated with implementing one soil enrichment practice are largely unknown, the financial outcome of implementing combinations of multiple soil enrichment practices is even more uncertain. Furthermore, soil enrichment activities encompass an enormous variety of practices, with tremendous potential for development of new practices. It would not be practical or even feasible to compile financial data on the full suite of existing practices much less potential future practices. This protocol adopts a standardized method for the determination of additionality for the project activity class based on demonstration of widespread risk aversion in the agricultural sector globally. This appendix includes an assessment of behavior in the agricultural sector that is not focused solely on long-term profitability, but rather is driven by a wide variety of motivations, including local agricultural tradition and cultural inertia that slows the adoption of new agricultural practices. While all humans make decisions in certain aspects of their lives that are not purely driven by economic factors, farming as a commercial enterprise faces unique conditions which accentuate the importance of values other than long-term profitability and the ramifications of decision-making that incorporates such values. Revenue from the sale of GHG credits may work to surmount such barriers to new practice adoption by financing the work of project proponents to address barriers related to cultural tradition and to perceptions of risk associated with the adoption of soil enrichment practices. GHG credit revenues may enhance the potential magnitude of the profitability of practice change(s), while also accelerating the timeline of those gains.

Studies of these barriers to practice adoption demonstrate it is difficult to get farmers to change their behavior for a variety of reasons. Research conducted via grower interviews focused on identifying the psychological barriers to the adoption of soil enrichment practices. These conversations highlighted barriers to soil enrichment practice adoption including:

- Barriers associated with existing market structures and a lack of motivating incentives to get farmers to shift practices.
- Barriers associated with whether farmers believe they can feasibly adopt new practices, implications of decisions, and their feelings towards risk.
- Barriers associated with openness to new ideas, the perceived magnitude of the shift, and their trust of the messenger.
- Barriers associated with the story farmers tell themselves about who they are, their values, and how they fit into their community.

The presence and influence of these barriers are supported by the larger consensus of peer reviewed research, as detailed in Section A.2.

A.2 Farmer Decision Making Under High Uncertainty and High Risk

Significant academic research has explored the subject of farmer decision making, seeking to develop a stronger understanding of motivations and decision-making factors. Until recently, much of the academic literature used an economic rationalizer/maximizer lens that made significant assumptions about the motives or decision-making methods as well as condition or context in which farmers make decisions. This traditional economics approach often concluded that increased economic incentives would drive grower decisions to adopt practices with reduced environmental and societal externalities. Under that approach, simply paying farmers more for better practices would provide clear information that farmers would include in their decision making toward a more rational economic outcome.

More recent research has focused on questioning and analyzing the actual pathways to farmer decision making. If in fact farmers are not focused purely on long-term profitability (as exemplified from the past 40 years of conservation subsidization at state and federal levels)[27], just how (and why) do they make their decisions? What are the key factors that determine adoption of new practices? How might government or private market programs best approach farmers to encourage behavior change to address numerous externalities?

To fully understand farmer decision making, one must start with understanding the context in which they operate. If farmers were to make decisions based purely on maximization of long-term profitability, they would need the right conditions to support such decision-making. Those include having clear and accurate information, responsive and timely outcomes to decisions, few uncontrollable variables, and minimal barriers to adjusting decisions and behaviors. This context works for basic quick and repeated consumer purchasing decisions within well-established markets involving many buyers and sellers. However, farmers' situations are quite different from that ideal. Farmers experience considerable uncontrolled variables in their farming. From weather to markets to pests and diseases, farmers are almost entirely reliant on factors outside of their control (Menapace, Colson, & Raffaelli, 2012). They also experience a long delay between decision and outcome, often months and sometimes years between the initial decision and receiving first evidence of success or failure due to the length of agronomic and economic cycles. Farmers also experience considerable initial costs to changing practices, often with long payback periods (Aimin, 2010). Thus, despite evidence that soil enrichment practices may increase long-term profitability, while also potentially making farms more resilient to changes in some of the uncontrolled variables mentioned above, the natural and economic realities described above hinder adoption of these practice changes.

There are also structural barriers faced by growers who want to implement certain practice changes. Crop insurance is an area of particular importance in this regard. In order to achieve financial protection against crop performance problems, most growers enroll in some form of government-sponsored crop insurance. However, these programs generally have very prescriptive activity requirements. In some cases, these requirements can slow, or completely prevent, adoption of soil enrichment practices. For example, when growers experience a "prevented plant," where weather conditions delayed planting of a crop within the appropriate time window, they face restrictions on the use of cover crops, resulting in many acres remaining fallow for an entire season.

This context has a significant impact in how farmers make decisions, from their cropping choices to their social interactions. In addition, farmers make occupational and other significant decisions using a range of values. While it is true that many people in many occupations make choices using a range of values, from economic utility to enjoyment of the occupation to social benefits, these additional values play a heightened role for many farmers due to the heightened degree to which their occupations both enable and compel them to embrace values of independence and family-based lifestyle, relative to other professions. This largely arises from the fact that farming is not a "job" in the conventional sense because the farm is not only a commercial enterprise, but also a home, a legacy, and a personal identity. In this context, personal and commercial decisions cannot be decoupled. This is a truly unique context in which few others experience the level of uncertainty and risk combined with opportunity of social non-

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[27] Despite the fact that many of the official USDA NRCS Conservation Practice Standards can enhance long-term profitability of agricultural operations, and have been promoted for decades, these standards have only been adopted at any significant scale in response to direct incentive payments from government programs.

pecuniary values. These factors, particularly when combined with the public nature of agriculture in which practices are readily visible to others, makes it open to intense scrutiny by those outside and inside of farmers' social networks. This can impact their identity and compel them to implement strategies to satisfy internal identity and external social pressure, as opposed to simply maximizing economic outcomes.

This combination of factors leads farmers to pursue decision-making that is not purely driven by economic factors, for instance by seeking risk avoidance as a primary goal (Stuart, 2014) (Menapace, Colson, & Raffaelli, 2012). Due to long delays between decisions and outcomes, coupled with the reality that they have literally thousands of different options within a context of thousands of different conditions due to multiple uncontrolled variables, farmers seek to restrict the range of choices they need to consider. The primary method by which they restrict choices is through satisficing (Dayde, Couture, Garci, & Martin-Clouaire, 2014). Farmers employ a range of filters to sift out unacceptable options. Some filters include initial capital cost, social norms, and fit with identity (Findlater, Satterfield, & Kandlikar, 2019). Initial capital cost is an obvious filter, as finances rationally constrain options. Financial support for the adoption of improved practices can successfully aid farmers in overcoming this natural barrier. Social norms and identity, however, reflect satisficing strategies that significantly constrain the boundaries of viable options for farmers and, at the same time, have little response to financial incentives. Farmers, as commercial enterprises, are strongly influenced by social norms to a greater degree relative to those in other occupations (Sutherland, et al., 1996) (Liu, Bruins, & Herberling, 2003). Farmers' perception of risk of a practice is correlated to perception of that practice fitting social norms (Singh, Dorward, & Osbahr, 2016). The fear of peer shaming and the desire for peer validation through alignment of implemented practice to social norm further restricts farmer consideration of otherwise economically rational or agronomically viable farming practices (Findlater, Satterfield, & Kandlikar, 2019), (Earls, 2009).

Additionally, farmers limit the distance into the future in which they will address problems as well as employ heuristics, or past experience, to further limit the decisions they need to make and options or strategies they are willing to consider (Findlater, Satterfield, & Kandlikar, 2019). This is a strategy to minimize decision paralysis brought on by the overwhelming number of future scenarios and choices farmers could make in a world with considerable variables and high uncertainty. Farmers will also use heuristics to provide mental models or metaphors through which to understand fairly abstract agronomic strategies (Dayde, Couture, Garci, & Martin-Clouaire, 2014). Human decision tendencies will also incline farmers to place more emphasis on risk avoidance than profit maximization in high risk scenarios. These strategies put a heavy emphasis on past experiences as guides for the future, in the process resulting in decision making that heavily emphasizes the status quo (Kahneman, 2003), (Dayde, Couture, Garci, & Martin-Clouaire, 2014), and (Aimin, 2010). Only after options have passed through these filters may they be considered viable, regardless of potential profitability or available financial incentives.

Another thread of research examining farmer decision making has explored the role of identity. Decisions, especially those with long delays (risk) and numerous variables (uncertainty) will be increasingly influenced by an individual's identity, which fills in the void of certainty and clear information. Behavior becomes the tool by which humans express their identity in particular settings. For farmers, the tool of expression is visible agronomic practices, which are readily observable by others in their desired community/identity. This visibility further accentuates the role of identity and implementing behaviors to adhere to perceived actions befitting a particular identity. Future decisions get influenced by the perceived or expected feedback received from others in their community. The same can be said for many others in society, but these pressures are accentuated for farmers insofar as they are also sole actors in a commercial enterprise, and as they operate in particularly high-risk, low control environments (greatly at the mercy of external factors such as weather). In light of this expected feedback, farmers will adjust behaviors to receive positive feedback and avoid negative feedback (McGuire, Wright Morton, & Cast, 2013), (Liu, Bruins, & Herberling, 2003). Farmers also overwhelmingly see themselves as "good farmers." When new practices are presented as advantageous or better than their current practices, farmers perceive such practices as a threat to that identity. In that situation, people will seek to disregard, discount, or deny new evidence rather than having to view themselves as not adhering to their primary identity (Syed, 2015). In some situations, farmers may not necessarily see the suggestion of a new practice as an immediate threat to their identity; however, their limited knowledge of implementing that new practice may result in the same process and outcome of avoiding implementation in order to avoid failure (either in ability to implement or in crop yield outcome of reduced crop yields) that would challenge their identity as a good farmer (Wilson, Schlea, Boles, & Redder, 2018), (Stuart, 2014).

Based on this more complete understanding of farmer decision making, key strategies may be implemented to improve efforts to move farmers to adopting practices that exhibit positive economic outcomes with reductions in environmental externalities. As indicated, simply increasing the long-term financial return of preferred practices is insufficient to change behaviors (Howley, Buckley, O'Donoghue, & Ryan, 2014). As such, financial incentives (such as carbon offset revenues) should be designed and offered with risk reduction as the primary purpose and should be communicated as such to farmers. Framing preferred practices as key risk-mitigating strategies will be vital to accomplish broad adoption goals. Further, preferred agronomic practices must be presented in ways that allow farmers to see how such practices fit existing social norms and farmers' identity. Finally, outreach must include efforts to simplify implementation to increase farmer perception of self-efficacy. Ultimately though, our contention is that it is not necessary for this protocol to mandate the broadest suite of actions to comprehensively address all aspects of the various barriers faced by farmers. Instead, we contend it is sufficient for us to demonstrate that providing offset revenues and mandating robust GHG accounting and longevity of SOC impacts—with proper incentives to ensure such longevity—is sufficiently unique to make projects under this protocol additional.

A.3 Trends in Adoption of Soil Enrichment Practices

As shown in a long-term assessment published by the USDA, conservation practices which have been promoted by the department, mainly through the NRCS, have seen mixed levels of success in recent decades (Baranski, et al., 2018). For certain crops, in certain regions, certain practices have increased adoption, while other combinations of these have seen flat or decreasing adoption rates. Nationally, there are few clear success stories. While no-till farming has made strong gains in wheat, it has remained flat for corn, and showed losses for soybeans. What the data do not show, however, is the extent to which these practices are maintained over the long term, and to what extent they are effective at generating environmental benefit, especially in regard to GHG impacts. By focusing on measured performance, and requiring permanence, the SEP is setting a higher bar for the application of sustainable agricultural practices over a long period of time.

A.4 Discrete Change and Practice Adoption Over Time

Offset project protocols normally conceptualize the project activity as a single, binary event. The project begins on the start date, fully formed, and continues operation largely unchanged through the entirety of the crediting period. For example, a landfill gas control system begins operation at a discrete point in time and operates fairly continuously for decades. The "baseline" period and the “project” period are clearly defined. However, with agricultural land management, this is often not the case, further complicating the approach to determining additionality. Many farmers have to make at least minor adaptations from year to year for weather and market conditions. However, as described in earlier sections, they make these management decisions based on conventional wisdom and business as usual practices. Not only are there significant barriers to a single change in practice, but these barriers are compounded when a farmer is faced with the prospect of multiple practice changes to achieve the full benefits of sustainable agricultural land management. In reality, farmers will tend to adopt new practices in a piecemeal way, going further into sustainable management only when they are comfortable with the performance of the initial steps (Brown, 2018).

Thus, a single practice change is likely to be the only viable point of entry for the majority of conventional farmers. At the same time, it is also likely to lead to multiple practice changes over time as the farmer’s comfort level increases and they begin to understand better the linkage between practice change and offset revenue.

Appendix B Illustrative List of Soil Enrichment Practices

As described in Section 3.4.1, a soil enrichment project must adopt one or more changes in pre-existing agricultural management practices which are reasonably expected (over the project crediting period) to increase SOC storage and/or reduce emissions of CO_2, CH_4, and/or N_2O from agricultural land management activities.

Land management practices considered for soil enrichment projects are those which are expected to achieve one or more of the following results on the project area:

- Increased duration of the presence of living roots in the soil;
- Reduced chemical inputs (particularly nitrogen fertilizers)[28];
- Reduced use of fossil fuels, or electricity, for the operation of equipment;
- Reduced or eliminated mechanical disturbance of the soil;
- Increased diversity of plant species cultivated in regular cycles;
- Protection of top soils (soil armor);
- Integration of beneficial livestock practices.

Table B.1, below, lists several potential practice changes which could be eligible to define a soil enrichment project. This list is not comprehensive.

Table B.1. Illustrative List of Soil Enrichment Project Activities

Category	Suggested Practice Changes
Crop selection and rotation	▪ [baseline practice, not eligible for additionality] Continuous cash crop (monoculture) ▪ Rotational (2 crop) cash crop ▪ Rotational (3+ crop) cash crop ▪ Continuous cash crop with cover crop ▪ Rotational cash crop (2 crop) with cover crop ▪ Rotational cash crop (3+ crop) with cover crop ▪ Continuous cash crop planting into living cover crop ▪ Rotational cash crop (2 crop) planting into living cover crop ▪ Rotational cash crop (3+ crop) planting into living cover crop ▪ Relay cropping ▪ Companion or intercropping of cover crop with cash crop during the same growing season
Use of cover crops	▪ Plant cover crops, annual ▪ Plant cover crops, perennial ▪ Plant leguminous cover crops, annual ▪ Plant leguminous cover crops, perennial ▪ Plant multi-species cover crops, annual ▪ Plant multi-species cover crops, perennial ▪ Interseeding cover crops, annual/perennial ▪ Interseeding leguminous cover crops, annual/perennial ▪ Interseeding multi-species blend cover crops, annual/perennial

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[28] There may also be non-GHG positive impacts, or co-benefits, associated with a reduction in the use of other chemical inputs, such as pesticides, however the quantification approach in this protocol will focus on GHG impacts of fertilizers, and not include estimation of the GHG impacts of reduced use of other chemicals.

Category	Suggested Practice Changes
Tillage	▪ Moldboard (2-10”) (baseline practice, not eligible for additionality) ▪ Disk/chisel (2-10”), <50% residue remaining ▪ Disk/chisel (2-10”), >50% residue remaining ▪ Vertical tillage (1-2”), <50% residue remaining ▪ Vertical tillage (1-2”), >50% residue remaining ▪ Strip till, <50% residue remaining ▪ Strip till, >50% residue remaining ▪ No-till (annual basis, alternating with tillage in other years of the rotation) ▪ Continuous no-till (no tillage throughout the entire crop rotation)
Fertilizer management	▪ Synthetic fertilizer without optimization (baseline practice, not eligible for additionality) ▪ Synthetic fertilizer: optimize application or practice split application, surface applied or broadcast ▪ Synthetic fertilizer: optimize application or practice split application, and apply subsurface or with controlled-release (nitrogen stabilizer) ▪ Organic fertilizers
Irrigation management	▪ Flood irrigation ▪ Standard irrigation (defined as >X gal/ac) ▪ Standard irrigation (defined as <X gal/ac) ▪ No irrigation ▪ Rice only: Minimize annual flood days (<X days/year)
Livestock management	▪ Stock pasture (no rotation) ▪ Rotational pasture (rotate every 2+ days) ▪ Multi-species rotational pasture ▪ Rotational pasture (rotate every day or more frequently)

Appendix C Assessing Leakage for SEP Projects

This protocol requires monitoring and accounting for the potential leakage related to the project activities in cases where livestock are displaced out of the project area or there is a sustained reduction in yield from primary cash crops. There is precedence in carbon accounting for limiting the need for accounting for leakage where the project activities occur on land used for agricultural production, such as section 3.7.12 of the VCS Methodology Requirements v4.0 (Verra, 2019). Under these VCS requirements projects must develop a project description that includes a commitment to no substantive leakage, and thus commit to ensuring no such leakage takes place. Under the VCS requirements projects must also account for any activity-shifting leakage associated with reduced stocking of the project area during the reporting period, relative to baseline historical stocking rates.

The main concern around leakage for soil enrichment projects would be through a reduction in commodity yield caused by project activities or displacement of livestock grazing activities. In theory, reduced output from project fields would result in increased output from fields outside of the project, either through increased efficiency (no leakage) or through conversion of new land for commodity production (leakage). This conversion of new land could be through activity shifting leakage, whereby the grower converts other acres under their control, or market shifting leakage, whereby other growers convert new acres to commodity production.

A meta-analysis of 610 studies concerned with the effects of no-till, use of cover crops or significant crop residues, and use of crop rotations found that there are potential short-term declines in crop yield, but that these short term effects are recovered over time, with no significant loss in yield as practices are maintained for several years (Pittelkow, et al., 2014). A soil enrichment project crediting period is 30 years, which is more than sufficient to erase these potential short-term yield declines. Thus, the approach to monitoring and assessing leakage related to cash crop yield declines adopted by this protocol relies on a government metric for long-term yield (see Section 5.5).

The agricultural sector is subject to many barriers to change (as discussed in Appendix A) and inefficiencies. Decreased yields would need to be large and sustained over time in order to generate sufficient incentive for land conversion elsewhere. Decreases of this magnitude are not expected from soil enrichment project activities. Importantly, there are two forces limiting significant yield declines on the project area:

1. **Farmer risk aversion**

   As discussed in Appendix A, farmers are incredibly risk averse. Decline in yield has an immediate and directly correlated effect on farm income. The revenue from carbon credits is meant to overcome the costs associated with adopting new management practices and behavior changes. Carbon revenues are not designed to replace the farmers' primary source of income: crop production. Any significant yield decline is likely to cause a farmer to exit the program and resume their pre-existing management regime, thus avoiding market-shifting leakage.

2. **Quantification of emission reductions**

   A secondary guardrail against significant yield declines is the fact that productivity is linked to the predicted SOC accumulation in biogeochemical models. The yield at harvest is one of the most sensitive dependent variables to a biogeochemical model predicting SOC. A lower yield will cause the model to assume the field was less productive, and lead to fewer emission reductions because of reduced SOC accumulation. Thus, there is an in-built incentive to maintain yields in order to enhance crediting for emission reductions.

Based on the above, this protocol adopts a targeted approach to assessing and accounting for potential emissions leakage from soil enrichment project activities. By comparing yield trends in the project area to yield trends in the relevant region, it is possible to detect declines related to project activities separately from overall market shifts due to weather, genetics, and market conditions.

Appendix D Quantifying Uncertainty

An estimate of $\overline{ER_t}$, denoted by $\widehat{\overline{ER_t}}$, is made using measurements and model predictions on a subset of the project. Three sources of error contribute to the uncertainty of $\overline{ER_t}$, and each of these sources of error must be estimated:

1. **Sample error** resulting from measuring and modeling only a portion of the project
2. **Measurement errors** of inputs to the model
3. **Model prediction errors**

The uncertainty of $\widehat{\overline{ER_t}}$ is captured by the margin of error, which is the half-width of the 95% confidence interval:

Equation D.1.

$$\boldsymbol{ME_{\widehat{\overline{ER_t}}} = t_{\alpha,df}\, s_{\widehat{\overline{ER_t}}}}$$

Where,

$t_{\alpha,\mathrm{df}}$ = Critical value of a *t*-distribution for significance level $\alpha = 0.05$ (i.e., a $1 - \alpha = 95\%$ confidence interval) and df is the degrees of freedom appropriate for the sampling design used

$s_{\widehat{\overline{ER_t}}}$ = Standard error of $\widehat{\overline{ER_t}}$

It is assumed that errors in estimating the various gases and pools are independent, so the standard error of $\widehat{\overline{ER_t}}$ in Equation D.2 is the square root of the sum of variances of the gases:

Equation D.2.

$$\boldsymbol{s_{\widehat{\overline{ER_t}}} = \sqrt{\sum_{gases\ G} s^2_{\widehat{\overline{\Delta G_t}}}}}$$

D.1 Uncertainty Deduction

If the uncertainty of the estimated emissions reduction is too large, then an uncertainty deduction (*UNC*$_t$) is applied by multiplying by 1 – *UNC*$_t$. The uncertainty deduction is the extent to which the margin of error (Equation D.1) of the average emissions reduction exceeds 15% of the estimated average emissions reduction, $\widehat{\overline{ER_t}}$:

Equation D.3.

$$\boldsymbol{UNC_t = MIN\left(100\%, MAX\left(0, \frac{ME_{\widehat{\overline{ER_t}}}}{\widehat{\overline{ER_t}}} - 15\%\right)\right)}$$

Where,

$\widehat{\overline{ER_t}}$ = Estimated per-acre average emission reduction across monitoring period t

$ME_{\widehat{\overline{ER_t}}}$ = Margin of error of the 95% confidence interval (Equation D.1)

D.2 Model Prediction Error

Errors of the model are calculated from validation datasets where ground truth measurements of emissions can be compared with the model's predictions. Assuming that the model is approximately unbiased, the uncertainty of a model prediction is captured by the variance of its errors, which are estimated using validation datasets.

The ideal validation data would be field trials in which practices that simulate a project scenario are used in one part of the field and practices that simulate a baseline scenario are used in another part of the same field. Then errors of the project minus baseline emissions reduction of a certain gas or pool, ΔG_t, can be computed directly at each site *i* using $error_{\Delta G,i} = \widehat{\Delta G_i} - \Delta G_i$, and the uncertainty from the model is estimated as the variance of $error_{\Delta G,i}$ across all sites i in the validation data.

Because such field trials (and associated model predictions) are rare, the task can be split into two separate tasks:

1. model predictions and ground truth measurements can be used to estimate typical errors of the prediction of emissions in just one scenario (e.g., just the project scenario), and
2. the correlation of errors between project and baseline scenarios can be estimated from the field trials described above.

Assuming that the variance of the model prediction is the same in the project and baseline scenarios [i.e., $\boldsymbol{Var(\widehat{G_{wp}}) = Var(\widehat{G_{bsl}})}$, which we denote by $s^2_{model,G}$], we have

$$\boldsymbol{Var(\widehat{\Delta G}) \equiv Var(\widehat{G_{bsl}} - \widehat{G_{wp}}) = 2\,[s^2_{model,G} - Cov(\widehat{G_{bsl}}, \widehat{G_{wp}})]}$$

By writing $Cov(\widehat{G_{bsl}}, \widehat{G_{wp}})$ in terms of a correlation coefficient:

Equation D.4.

$$\boldsymbol{\rho = \frac{Cov(\widehat{G_{bsl}}, \widehat{G_{wp}})}{\sqrt{Var(\widehat{G_{wp}})\ Var(\widehat{G_{bsl}})}}}$$

We have:

Equation D.5.

$$\boldsymbol{s^2_{model,\Delta G} \equiv Var(\widehat{\Delta G}) = 2\,s^2_{model,G}\,(1 - \rho)}$$

Where,

$s^2_{model,\widehat{\Delta G}}$ = Estimated variance of the model's prediction of the baseline-minus-project difference in emissions of gas or pool G at one location

$s^2_{model,G}$ = Estimated variance of errors made by the model's prediction of emissions of the gas or pool G (estimated from measurements in fields that need not be side-by-side trials with baseline and project scenarios)

ρ = Correlation of errors in project and baseline scenario pairs (which is estimated from side-by-side field trials with baseline and project scenarios)

Because side-by-side trials are rare, ρ is estimated from fewer data points than $s^2_{\text{model},G}$. Data for quantifying model structural error may be sourced from studies conducted external to the project area, and the data shall be from the same datasets used to validate that the model is unbiased (per guidance document on Model Calibration, Validation, and Verification Guidance for Soil Enrichment Projects).

If the amount of data for quantifying model structural uncertainty varies significantly among crops and regions, then a structural model uncertainty could be estimated for groups of similar sites (e.g., based on a stratification applied to the fields in the project and to the sites in the validation data, or based on a Gaussian Process fit to the validation data with biophysical variables, management practices, and/or other variables as predictors). That way, a structural model uncertainty can be assigned to each field *i*: $s^2_{\text{model},\Delta G,i}$.

D.3 Model Input Measurement Error

Inputs to the model are measured with error. Provided that these measurement errors are uncorrelated across sample points, these errors are automatically captured by the estimate of sample error, discussed below. [See, for example, Cochran (1977, p. 382); de Gruijter et al. (2006, p. 82); Som (1995, p. 438).] QA/QC procedures for model inputs ensure that model inputs are sufficiently accurate and that measurement errors are uncorrelated with each other.

D.4 Sample and Measurement Error

Here, we give an example of a two-stage design with first-stage units chosen with probability proportional to their acreage (with replacement) and with second-stage units chosen with simple random sampling (with replacement). For example, the first-stage units could be fields that are tiled with a fine grid; the second-stage units are tiles within the grid. This design could be modified in many ways, for example by assigning fields to strata, or by eliminating fields as a sampling unit and instead creating strata of tiles. Sample designs that select fields without replacement may also be used, provided that the estimators of variance are changed accordingly (see, e.g., Tillé 2006, chapters 5 and 7).

In the first stage, n out of N fields are selected with probability proportional to their acreage with replacement. (For example, accumulate field sizes to form intervals of length equal to each field's area: $[0, A_1)$, $[A_1, A_1 + A_2)$, $[A_1 + A_2, A_1 + A_2 + A_3)$, …, $(A_1 + \ldots + A_{N-1}, A_0)$; then draw n numbers randomly between 0 and the total area A_0, and for each draw record which field's interval it falls into.) If a field is chosen multiple times, then tiles are independently selected from that field multiple times. Subsequent calculations are simplified by making the probability $\boldsymbol{\pi_i}$ of selecting field i equal to its area A_i divided by the total area A_0 of all fields at the time of randomization, i.e., probability proportional to size (PPS) sampling:

Equation D.6.

$$\boldsymbol{\pi_i = \frac{A_i}{A_0}}$$

Within each selected field i, m_i tiles are chosen with simple random sampling with replacement. The estimator of the emissions reduction averaged across all tiles is the simple (unweighted) average across all sampled fields and sampled tiles [Som (1995), eq. 16.19; Cochran (1977), eq. 11.39]:

Equation D.7.

$$\widehat{\widehat{\boldsymbol{\Delta G_t}}} = \frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \widehat{\widehat{\boldsymbol{\Delta G_{i,t}}}} = \frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \frac{\mathbf{1}}{\boldsymbol{m_i}}\sum_{\boldsymbol{j=1}}^{\boldsymbol{m_i}} \widehat{\Delta G_{i,j,t}}$$

Where,

$\widehat{\widehat{\Delta G_t}}$ = Estimated average emissions reduction of gas or pool G in year t, in tCO2e/acre/year

$\widehat{\widehat{\Delta G_{i,t}}}$ = Estimated average emissions reduction of gas or pool *G* in year *t* in field *i*, in tCO2e/acre/year

$\widehat{\Delta G_{i,j,t}}$ = Estimated emissions reduction of pool G at point j in field i, in tCO2e/acre/year.

n = Number of sampled fields (and the sampled fields are assumed to have indices $1, 2, \dots, n$)

To fix the amount of work in each field, set m_i equal to a constant m across all fields. Then the design becomes "self-weighting," and Equation D.7 simplifies to an average across all measurements, $\widehat{\widehat{\boldsymbol{\Delta G_t}}} = \frac{\mathbf{1}}{\boldsymbol{n\,m}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}\sum_{\boldsymbol{j=1}}^{\boldsymbol{m}} \widehat{\Delta G_{i,j,t}}$.

Ignoring model errors, an unbiased estimator of the variance of $\widehat{\widehat{\Delta G_t}}$ is, from [Som (1995), eq. 16.19; Cochran (1977), eq. 11.40],

Equation D.8.

$$\boldsymbol{s^2_{sample\,\&\,meas.,\Delta G,t}} = \frac{\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}\left(\widehat{\widehat{\boldsymbol{\Delta G_{i,t}}}} - \widehat{\widehat{\boldsymbol{\Delta G_t}}}\right)^{\mathbf{2}}}{\boldsymbol{n\,(n-1)}}$$

D.5 Combined Uncertainty

To combine variance from model error (Section D.2) with measurement and sample error (Section D.4), we assume that the model errors are uncorrelated with the measurement values and are independent across samples. Then by [Cochran (1977), eq. 13.39; Som (1995), eq. 25.10], the variance of $\widehat{\widehat{\Delta G_t}}$ incorporating sample error, measurement error, and model prediction error is

Equation D.9.

$$\boldsymbol{s^2_{\Delta G,t}} = \boldsymbol{s^2_{sample\,\&\,meas.,\Delta G,t}} + \frac{\boldsymbol{s^{\;2}_{struct,\Delta G,t}}}{\boldsymbol{n \times m}}$$

D.6 Remeasured Soil Carbon Stocks

When the change in soil organic carbon stocks is periodically directly re-measured, uncertainties of model inputs and model prediction are eliminated from the project scenario. The estimate of the change in average carbon stocks in the project scenario from period $t-1$ to t is unbiasedly estimated by the difference of the estimates at the two time periods [Som (1995), eq. 24.15]:

Equation D.10.

$$\overline{\widehat{SOC}_{wp,t}} - \overline{\widehat{SOC}_{wp,t-1}}.$$

If a whole new set of sample points is chosen independently of the initial sample points, then the variance of Equation D.10 is the sum of the variances [Som (1995), eq. 24.16]:

Equation D.11.

$$Var\left(\overline{\widehat{SOC}_{wp,t}} - \overline{\widehat{SOC}_{wp,t-1}}\right) = Var\left(\overline{\widehat{SOC}_{wp,t}}\right) + Var\left(\overline{\widehat{SOC}_{wp,t-1}}\right)$$

Because the carbon stock at a site is highly correlated with the stock at that same site at a later date (with correlation coefficient denoted by ρ_S), it is better to revisit the original set of sample points, so that, from [Som (1995), eq. 24.17],

Equation D.12.

$$Var\left(\overline{\widehat{SOC}_{wp,t}} - \overline{\widehat{SOC}_{wp,t-1}}\right) = Var\left(\overline{\widehat{SOC}_{wp,t}}\right) + Var\left(\overline{\widehat{SOC}_{wp,t-1}}\right) - 2\,\rho_S\sqrt{Var\left(\overline{\widehat{SOC}_{wp,t}}\right)\,Var\left(\overline{\widehat{SOC}_{wp,t-1}}\right)}$$

D.7 References

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