**The Regenerative Standard**

**Regenerative Soil Organic Carbon Methodology   
for Rangeland, Grassland, Agricultural, and Conservation Lands**

**Version 2.0 (FOR FINAL REVIEW)**April 10, 2025   
  
**Open-Access**





# Preface

[The Regenerative Standard (TRS)](http://regenerativestandard.org) is a family of methods, authored by scientists, focused on regeneration and restoration of ecosystem services (Soil Health, Water, and Biodiversity) including on working lands. This document is focused on the Regenerative Soil Organic Carbon Methodology (TRS SOC), the first method available under TRS. Subsequent methods in development are focused on water resources and biodiversity; ultimately creating a suite of methods meant to quantify full system restoration. Forthcoming methods under TRS will introduce improved quantification tools for measure-to-measure, robust and reliable ecosystem metrics for these focal areas. Each method under TRS is an open access, living document that has been developed from the body of science, from peer reviewed publications, and expertise under each topical area and will be continuously improved as new research and technologies are reviewed.

The core technical foundations of the Soil Organic Carbon Methodology (TRS SOC) are based upon the original [The Earth Partners, Soil Carbon Quantification Methodology](#VM0021), which was written, tested, and published over decades by a distinguished team of soil carbon scientists and authors of books, technical papers, and synthesis publications on agricultural soil carbon and the potential role of regenerated agricultural systems as a climate mitigation strategy, including many of the authors found in Kimble et al (2007), Paul et al (1997), Daniel and Hammer (1992) and others. This method was subsequently VCS approved and released as Verra VM0021 Soil Carbon Quantification Methodology. Ownership, authorship, and copyright of VM0021 and the 20 chapters under VM0021 is now held by Applied Ecological Institute and is referenced throughout TRS SOC as these methods are still the best available and used by many other protocols i.e. VM0042 and BCarbon. See [Appendix 6.0](#TRS_history) for the full history and lineage.

While building upon the earlier methods, TRS SOC is an independent and original method that has been continuously developed and refined over millions of acres of sampling, resampling and carbon quantification. The Verra VM0021 Soil Carbon Quantification Methodology has been strengthened, modernized, reorganized, and streamlined to reduce costs, ensure scalability, and confirm accuracy, precision and robustness to support high quality, trustable carbon credits.

## Table of Contents

[Preface 1](#_Toc180594469)

[Introduction 4](#_Toc180594471)

[Definitions and Acronyms Used 7](#_Toc180594473)

[Project Framework 18](#_Toc180594474)

[Project Requirements 20](#_Toc180594475)

[Task 1. Project Overview - Identification and Eligibility of Project Activity 20](#_Toc180594476)

**[Task 1.1. Data confidentiality statement 20](#_Toc180594477)**

**[Task 1.2. Physical Address of the Properties Submitted for Certification 21](#_Toc180594478)**

**[Task 1.3. Description of Land Management Activity 21](#_Toc180594479)**

**[Task 1.4. Project Eligibility 21](#_Toc180594480)**

**[Task 1.5. Project Boundary 26](#_Toc180594481)**

**[Task 1.6. Baseline Scenario 27](#_Toc180594482)**

**[Task 1.7. Additionality 29](#_Toc180594483)**

**[Task 1.8. Permanence 34](#_Toc180594484)**

**[Task 1.9. Credit Release 49](#_Toc180594485)**

**[Task 1.10. Contractual Commitment 49](#_Toc180594486)**

[Task 2. Measurement and Reporting 49](#_Toc180594487)

**[Task 2.1. Quantification of Soil Carbon Stocks for Baseline and Project Scenarios 53](#_Toc180594488)**

**[Task 2.2. Ex-ante Projections of Project Emissions from Non-soil Carbon Sources 62](#_Toc180594489)**

**[Task 2.3. Ex-post Quantification of Project Emissions 68](#_Toc180594490)**

**[Task 2.4. Ex-ante Projection of Leakage 73](#_Toc180594491)**

**[Task 2.5. Ex-post Quantification of Project Leakage 75](#_Toc180594492)**

**[Task 2.6. Monitoring 77](#_Toc180594493)**

[Task 3. Interim Crediting Assessment (Optional) 77](#_Toc180594494)

**[Task 3.1. Projection of future soil carbon accrual rate for the project scenario 78](#_Toc180594495)**

[Task 4. Project Application Submission 81](#_Toc180594496)

[Task 5. Verification 83](#_Toc180594497)

[Task 6. Registration 84](#_Toc180594498)

[Appendix 1.0 Verification Guidance and Checklists 88](#_Toc180594499)

[Appendix 3.0 Guidance on Potential Emerging Technologies Being Tested to Monitor and Measure Grazing Land Use Changes, and SOC Stocks 92](#_Toc180594500)

[Appendix 4.0 The Regenerative Standard SOC Methodologies 97](#_Toc180594501)

[Appendix 5.0 Verra VM0021 464](#_Toc180594849)

[Appendix 6.0 The Regenerative Standard History 498](#_Toc180594872)

[Appendix 7.0 Verra Links 503](#_Toc180594873)

**Appendix 8.0 Migrating from TRS Version 1.0 to 2.0………………………………………………………………………………..500**

**Appendix 9.0 Monitoring Period Funding for Monitoring Permanence and Protection for Reversals ………506**

# Introduction

The Regenerative Standard Soil Organic Carbon Method (TRS SOC), the first release of a family of methods under The Regenerative Standard (TRS), describes how carbon drawdown credits can be generated through nature-based, atmospheric carbon drawdown and soil carbon storage related to conservation, ecosystem restoration, and agricultural projects. It also applies to other projects where the management of soils directly or indirectly through management of hydrology, livestock, soil fertility, and plant diversity and productivity can improve soils, reduce erosion, and promote soil carbon storage.

TRS SOC ensures the delivery of high-quality, carbon removal credits, based on rigorous soil sampling, laboratory analysis, and independent third-party verification. To meet these objectives, TRS SOC combines best practices, rigor, and approaches from published work, and has been informed by several existing standards, including Verra, ISO, Climate Action Reserve, BCarbon, as well as guidelines from the [IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change, and Forestry](https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf). TRS SOC is focused on delivering proven, technical, and scientific innovation to produce high-quality carbon removal credits based on measurement to measurement improvements in soil carbon stocks over time. TRS SOC V2.0 includes updated guidelines on additionality and permanence with adequate safeguards to ensure results are real, measurable, and verifiable. Version 2.0 does not allow for avoided conversions, defined strictly protecting grasslands, conservation lands or perennial agricultural lands. It does however, should a carbon program developer wish, have allowances for documenting reductions in emissions such as in the conversion of row crop agricultural land to perennial grasslands, where fertilizers, and tillage related emissions are reduced or eliminated. Please see the glossary that differentiates between avoided conversion and reduced emissions of GHG’s. Many standards describe how carbon credits from nature-based soil carbon storage can be generated. However, TRS SOC emphasizes carbon removal credit quality while also making it easier for landowners to participate in nature-based carbon storage opportunities at scale. TRS SOC is designed to make it easier to initiate and participate in soil carbon storage project opportunities by removing typical participation barriers and requiring that crediting be based on bonified measurements of soil carbon stocks over time. TRS SOC is designed to allow future measured soil carbon benefits created by “Early Adopters” (see glossary) starting with the date of their enrollment, in a soil carbon project.

TRS SOC does not focus on any particular or specific activity change and allows land stewards to participate and innovate activities to sequester and store additional soil carbon. These two guideposts simplify who can be involved in carbon programs. To further expand participation and rapid scaling by land stewards, the measurement-to-measurement basis for crediting, requires that imported carbon materials such compost, manure, mulches, lime, or earthmoving that moves carbon (soils) around the landscape, are not allowed unless accounted for in the Project Plan.

TRS SOC is based on technical procedures detailed herein (and those incorporated through supporting references, such as to VM002 through VM0035, and others), in which the farmers, ranchers, or conservationists (“land stewards”) are focused on conservation, restoration, and regeneration on grazing, agricultural, or conservation lands. TRS SOC also offers guidance to allow Project Proponents to address and document additionality and permanence requirements in innovative ways to increase land steward participation.

TRS SOC is focused on carbon removal credits and does not include benefits from “avoided conversion emissions” but does allow for reduced emissions crediting (see glossary). Atmospheric carbon removal and reduced emission crediting storage is determined by conducting repeated measures of soil organic carbon (SOC) stocks. Only measure-to-measure increases, between T0 (***Time Zero***—the initial sample date at the start of the project) and T1 (***Time One***—the subsequent sample date often ranges from five to seven years later) produce creditable carbon credits. If a project proponent proposes to include reduced emissions crediting it also is to be based on direct measurement using repeated sampling as with soil organic carbon. Consequently, resampling time increments (See Expected Time Increments—in glossary) are up to the carbon program developer. This flexibility accounts for geographic differences, soil differences, ecological and agricultural cropping differences and growing season deviations from normal, and as such this extends through the life span of a project and Verification Period (see glossary). Flexibility in potentially lengthening the **Expected Time Increment**, and **Project Life Expectance** is warranted to assert accountancy, precision, and control over uncertainty through the robust measurement to measurement requirements under TRS SOC. Timing of sampling and the verification align to ensure the process is and representations have robust, rigorous, and transparent quantitative foundations underly crediting on any timeline (see **[Verification Checklist](#checklist_1)**).

Flexibility comes with annualized assurances of program compliance and incentives by allowing annualized crediting. Crediting can be calculated over any varying time horizons using literature predictions and, due to the measurement to measurement based crediting, and true-up of carbon stocks and thus by comparison of mean carbon stocks against the baseline at T0, during T1, T2 and so on. Using scientific literature on accrual rates, prior to T0 for projections, are trued-up against actual stock changes art T1. Following the collection of T1, conservative linear accrual rate assumptions, again are trued-up at T2.

Accountancy and ledger records of all crediting periods, the assignment of registered uniquely numbered certificates for each credit generated assures no double counting occurs. Regardless if credit is sold to one or multiple buyers, credit issuances of registered certificates safeguards confusion and miscounting or double counting (see **Registry Checklist**).

One-meter-deep (1m) soil sampling, analysis, and the generation of high-quality data is the foundation of TRS SOC, along with optional methods to estimate the carbon stocks and carbon stock changes over time (e.g., the rate of carbon accrual) that allow for revenue to Land Stewards in the interim years before T1 measurements are completed. This ensures Land Stewards can meet the financial challenges of implementing new management practices and therefore the quality of the credits registered through TRS SOC.

Forward-looking assessments for interim crediting are required to be followed by 1-meter-deep, direct soil sampling to establish the T0 baseline soil organic carbon, with subsequent 1-meter-deep sampling collected within an average of five to seven years to true-up the project soil carbon sequestration between the baseline T0 and final T1 soil sampling. Forward assessments used as the basis for interim crediting are required to be substantiated with actual field sampling results either reported in published and/or peer reviewed literature or measured by the Project Proponent using approved methods and technologies (see glossary for terms).

This document lays out the steps required to fulfill estimation, quantification, and application requirements for projects wishing to register credits under Nature’s Registry.[[1]](#footnote-2) TRS SOC V2.0 incorporates by reference, published modules for specific techniques and options for estimating, projecting, and measuring changes in specific carbon pools and emissions.

# Supporting References

* 1. [VM0026 *Methodology for Sustainable Grassland Management (SGM), v1.1*](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf)
  2. [VM0042 *Methodology for Improved Agricultural Land Management, v2.0*](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf)
  3. [TRS-1](#TRS_1) *[Methods to Determine Stratification, v1.0](#TRS_1)*
  4. [TRS-2](#TRS_2) *[Methods to Project Future Conditions, v1.0](#TRS_2)*
  5. [TRS-3](#TRS_3) *[Methods to Determine the Project Boundary, v1.0](#TRS_3)*
  6. [VMD0021\*\*](#VMD_0021) *[Estimation of Stocks in the Soil Carbon Pool, v1.0](#VMD_0021)*
  7. [TRS-4](#TRS_4) *[Estimation of Carbon Stocks in Living Plant Biomass, v1.0](#TRS_4)*
  8. [TRS-5](#TRS_5) *[Estimation of Carbon Stocks in the Litter Pool, v1.0](#TRS_5)*
  9. [TRS-6](#TRS_6) *[Estimation of Carbon Stocks in the Dead Wood Pool, v1.0](#TRS_6)*
  10. [TRS-7](#TRS_7) *[Estimation of Woody Biomass Harvesting and Utilization, v1.0](#TRS_7)*
  11. [TRS-9](#TRS_9) *[Estimation of Domesticated Animal Populations, v1.0](#TRS_9)*
  12. [TRS-8](#TRS_8) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool, v1.0](#TRS_8)*
  13. [TRS-10](#TRS_10) *[Estimation of Emissions from Domesticated Animals, v1.0](#TRS_10)*
  14. [TRS-11](#TRS_11) *[Estimation of Emissions of Non-CO2 GHG from Soils, v1.1](#TRS_11)*
  15. [TRS-12](#TRS_12) *[Estimation of Emissions from Power Equipment, v1.0](#TRS_12)*
  16. [TRS-13](#TRS_13) *[Estimation of Emissions from Burning, v1.0](#TRS_13)*
  17. [TRS-14](#TRS_14) *[Estimation of Emissions from Activity-Shifting Leakage, v1.0](#TRS_14)*
  18. [TRS-15](#TRS_15) *[Estimation of Emissions from Market Leakage, v1.0](#TRS_15)*
  19. [TRS-16](#TRS_16) *[Methods for Developing a Monitoring Plan, v1.0](#TRS_16)*
  20. [TRS-17](#TRS_17) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities, v1.0](#TRS_17)*
  21. [VT0001 *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities, v3.0*](https://verra.org/wp-content/uploads/imported/methodologies/VT0001v3.0.pdf)
  22. [BCarbon Soil Carbon Protocol Version 2](https://static1.squarespace.com/static/611691387b74c566a67f385d/t/649dbe7c3f1d2817d6edd473/1688059517354/Soil+Protocol.pdf)
  23. [CAR *Soil Enrichment Protocol, Version 1.0*](https://www.climateactionreserve.org/wp-content/uploads/2020/10/Soil-Enrichment-Protocol-V1.0.pdf)
  24. [ISO 14064 - *Part 2 Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*](https://www.iso.org/obp/ui#iso:std:iso:14064:-2:ed-2:v1:en)
  25. [ISO 14064 - *Part 3 Specification with guidance for the verification and validation of greenhouse gas statements*](https://www.iso.org/obp/ui#iso:std:iso:14064:-3:ed-2:v1:en)
  26. [AFOLU Non-Permanence Risk Tool](https://verra.org/wp-content/uploads/2019/09/AFOLU_Non-Permanence_Risk-Tool_v4.0.pdf)
  27. [VCS Validation and Verification Manual, v3.2](https://verra.org/wp-content/uploads/2018/03/VCS_Validation_Verification_Manual_v3.2.pdf)
  28. [VCS Program Definitions, v4.2](https://verra.org/wp-content/uploads/2022/12/vcs-program-definitions-v4.3-final.pdf)
  29. [VCS Risk Report Calculation Tool v4.0](https://verra.org/wp-content/uploads/2023/01/VCS-Risk-Report-Calculation-Tool-v4.0.xls)
  30. [VCS Standard v4.2](https://verra.org/wp-content/uploads/2022/02/VCS-Standard_v4.2.pdf)
  31. [CDM AR-ACM0003 Afforestation and reforestation of lands except wetlands --- Version 2.](https://cdm.unfccc.int/methodologies/DB/C9QS5G3CS8FW04MYYXDFOQDPXWM4OE)

\*\* Incorporation by reference of published and available protocols and technical publications (see references) include, for example, VM0021 and other numbered modules from The Earth Partners “Soil Carbon Quantification Method” as published and copyrighted (See Attachment 1)

# Definitions and Acronyms Used

**Activity Shifting Leakage:** Activities that are moved by local actors from within the project area to outside due to the project, and which result in losses of carbon in pools outside the project area.

**Additionality:** A criterion to determine whether emission removals and reductions are real, measurable, and in addition to what would have happened in the absence of the project. TRS SOC V2.0 offers four tests of additionality; an ultimate test is measure to measure increases in soil organic carbon stocks.

**Agent:** A person or organization undertaking actions that impact the management of carbon pools and emissions.

**Avoided Conversion GHG Emissions:** GHG emissions do not occur, because of a direct decision to protect land and its included carbon stocks.

**Avoided Conversion GHG Carbon Credits:** Under a baseline scenario, if a perennial agricultural landscape, or a working landscape (e.g. perennial native grassland) is proposed to be protected, rather than plowed up and converted to a corn cropland, TRS SOC currently does not support crediting for the protection of existing carbon stocks in the to be protected or already protected landscape. The rationale currently is that most conservation protection occurs using legal instruments such as conservation easements (or deed restriction). The value of the asset is determined by independent certified conservation appraisal and many assets, including generated ecological services values are more commonly now included as assets with donative value. To avoid conflicts such as double counting on the value of a protected landscape asset, and details of what is or is not included in conservation appraisal, currently we do not allow GHG emissions crediting with protection of land.

**Baseline:** The total amount of carbon within the project area in absence of the project.

**Baseline (Displaced):** Baseline may occur under TRS SOC where a baseline activity changes (is displaced) as a part of the planned activity change such as continuous grazing is replaced by Adaptive multi-paddock grazing, or a corn/soybean under a soil tillage rotation is replaced by no-till agriculture or a conversion to a perennialized cropping system requiring no tillage. For purposes of TRS SOC, because of the measurement to measurement carbon estimation and accounting, baseline displacement will be recorded as a change in activity and the actual on the ground changes will be measured and accounted for in carbon crediting. Where a displacement occurs special attention by the proponent and verifier through reassessing any subsequent leakage must also be documented with annual monitoring and reviewed during verification.

**Baseline Scenario:** The sequence of events and actions which would be expected to occur within the project area in the absence of the project.

**Buffer (Pool)**: A percentage of project carbon credits reserved by the Registry to address shortfalls and reversals, both avoidable and unavoidable, thereby ensuring that atmospheric carbon removal created by a project is secured and guaranteed. TRS SOC V2.0 offers three buffer pool assurance options so that carbon credits always represent actual measured improvements in soil organic carbon stocks on the ground.

**Conservative:** Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables.

**Coarse Fragments:** Pieces of rock or cemented soils > 2mm in diameter, and therefore too large to pass through the screen used in the laboratory prior to laboratory analyses.

**Crediting Period:** The time period for which GHG emission reductions or removals generated by the project are eligible for issuance as Verified Carbon Credits, not including any potential crediting period renewals. Also referred to as the “Project Crediting Period.” See **Post-Crediting Period Monitoring**

**Credit Year:** Each year during which credit is requested by the carbon project developer, and during which, a verification is conducted, and the registry may review certify and issue Verified Carbon Credits.

**Credit Yield:** The projected or measured carbon credits over the life of a soil carbon project, that can be annualized through projection based on science literature, but must ultimately be based and trued-up against on-the-ground measurements over time. The credit yield is to only be determined by remeasurement of soil carbon stock changes against time zero, baseline measurement.

**Constant Baseline:** is a baseline that may be constantly declining, increasing or be stable at a rate of change that does not change, where the trajectory does not vary. Compared to a static baseline’s which can fluctuate around a consistent mean rate of change but may not be the same at any point in time.

**Directly Attributable:** The change or effect occurs because of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be primarily and directly caused by the previous event in the chain. Analysis of the linkages in the chain should show that for each one, the previous event is at least 75% responsible for the next event. For this reason, the relationship between an event, or the actions of an agent, and the directly attributable effect, typically consists of not more than a few causal linkages.

**Early Adopters:** Land stewards who adopt a practice change, and culturally often are the leaders in the farming, ranching, and ecological restoration community. Early Adopters are often motivated by outcomes and benefits that may not be recognized or supported by programs, such as the Farm Bill, when they commence a new practice. Additionality in their case is often not financially motivated.

**Election of Option:** Project Proponent selection of definitional additionality and permanence requirements under TRS SOC V2.0.

**Enrolled Property Boundary**

Enrolled property is defined to have demonstrated through title and attached plat of survey, and other attachments to the PDD including but not limited to title or deed documenting fee ownership, or bonified lease or other form of legal control of the property, during the carbon contract term, which includes the post-contract term (e.g. 10 yrs.) must be documented in the PDD, reviewed and approved by the verification process.

To meet the enrolled property definition within a defined project, a carbon project developers must document the MLRA of each property and then give each property a unique nomenclature, that can specify the activity and time period of the project. This must be denoted in the PDD.

**Ex-ante:** Before the fact. Projection of values or conditions in the future.

**Ex-post:** After the fact. Estimation of values or conditions in the present or past.

**Expected Time Increments:** Carbon stock resampling timelines are not specified and have been left up to the project carbon developer. This is because the time from activity change initiation until statistically robust signals of change can be detected depends on growing conditions and plant productivity, geography, and meteorological year. In the midwestern USA under normal precipitation/growing conditions, often a 3-5 yr. lapsed time period is required; this extends to 7-10 years in semi-arid to arid rangelands.

**Forest:** A forest is a complex ecological system in which trees are the dominant life-form. There are many types of forests. And, also different expressions of the same forest. For example, in a forest system that experiences (and one often co-evolved with) wildfire, while live trees may be reduced to re-sprouting roots after fire, where trees are top-killed; or reduced entirely, initiating a recolonization process. Under this common scenario the same forest type, or even its recognition as a forest, may change depending on the classification used to identify the type of ecosystem present.

**Healthy Soil’s Co-Benefits**: Healthy soil supports healthy food, healthy livestock, and human nutrition, improves infiltration of precipitation to re-grow potable water supplies, can reduce flooding and costly flood damages, and the improvement of soil health may be one of the primary ways any (every) land steward can participate in improvement natural resources.

**Idea Note:** A document that summarizes a soil carbon project that is typically used to familiarize a registry, verifier, and potential buyers with the project. This is not a substitute for a project design plan.

**Land Management Activity Change:** Any change in crop, tillage, fertilizer, land drainage/water management, crop litter, livestock use (mass, density, stocking rate, rest-rotation), species or composition, amendment, invasive plant management technique changes (tillage, prescribed burning, herbicide or formulation, application method, flame or thermal management, smother-cropping, etc.), equipment or technical deployment, land-tenure and operations and staffing, are all accepted by definition as contributing to or resulting in a land management activity change.

**Long-lived wood products:** Products produced from harvested timber which is expected to persist and sequester carbon for an extended period – typically one hundred years unless there is a specific reason for using a different time.

**Minimum Soil Disturbance:** In TRS, under land management activity plans, as required to be documented in the proponents PDD, a clear description of the activity changes proposed and the level of land/vegetation disruption that may lead to temporary (14-60 days) or longer term (season or multi-season long) soil disruption must be documented. Soil disruption is defined as any activity resulting in bare soil of greater than 1 acre in size that is not cover cropped, mulched or protected from heating and wind and water erosion within 7 days of executing the activity that created the bare soil. Under most erosion control requirements and plans of federal and state governmental agencies any time soil is exposed and bare on greater than one acre, an erosion control plan and permit is required. Temporary soil disturbance on farms and ranches is typically associated with tillage or herbiciding followed by the installation of a cover crop or next crop, including perennial grasses in grazed lands. Typically, the soils are prepared and promptly (often in less than a week) the seed bed is drilled or broadcast with the next crop. Deviation from a prompt turn around, such as bare soil remaining exposed and subject to erosion, and soil organic carbon degradation, must be documented a priori in the PDD and reported annually in the project monitoring program. If the soil disturbance acreage is significantly large, new baseline sampling must be documented in an addendum to the PDD. The Minimum Soil disturbance must be demonstrated via satellite imagery analysis of bare soil annually and included in the monitoring report.

**Monitoring event:** The time at which monitoring of all the relevant variables is undertaken, to determine the net change in atmospheric carbon attributable to the project.

**Monitoring period:** The time specified in a PDD, during the project crediting period, and during the post-crediting period both require monitoring reports during which GHG emission removals and protection of the accrued carbon stocks occur, respectrively by each project.

**Monitoring plan:** Plan in which a monitoring schedule and methods will be documented as a part of the submittal to The Regenerative Standard, Verifier, and Nature’s Registry.

**Nature’s Registry:** This is a fully functional ledger, record keeping, and accountancy organization that reviews verification reports, certifies and issuances credits for projects that have used The Regenerative Standard, and any of the methods therein for quantification, reporting and verification. Nature’s Registry is a separate operating entity from The Regenerative Standard which is part of [Applied Ecological Institute, Inc](http://www.aeinstitute.org)., a 501c3.

**Organic Carbon (stocks):** Organic carbon is a large and diverse source of carbon-based compounds found within natural and engineered, terrestrial, aquatic and wetland environments. It is matter composed of organic compounds that have come fromfrom the feces and remains of organisms such as plant and animals. For purposes of Soil Organic Carbon, under the TRS SOC, all non-peat (i.e. hemic and fibric peat types) are eligible for crediting. Sapric peats (commonly referenced as “muck” soils) are eligible for inclusion and can be sampled under this methodology where they comprise a relatively thin layer on a prevalent soil system that is inorganic in nature, including hystic epipedon’s directly over bedrock or sand.

**Peatlands:** Land with a prevalence of hystic soils (e.g. sapric, hemic and fibric peat types) require different soil carbon measurement methods, that provide a permanently installed vertical reference gage or marker, so that soil strata thickness and Bulk density can be accurately measured over time. This marker is used to calibrate for shrink-swell and paludification dynamics that occurs under varying levels of saturation or inundation, and whether frozen or thawed. Consequently, land with hemic and fibric peat soil carbon is not addressable under TRS SOC at this time.

**Permanence:** Permanence is the long-term durability of soil organic carbon stocks, and TRS SOC uses a comprehensive permanence framework to establish a reasonable and adequate assurance that the atmospheric carbon removal created by a project is secured and guaranteed for at least 40 years. Regenerative grazing, farming, and restoration and management of conservation projects inherently contribute to the level of mineral associated carbon fractions. Each of these project types we have measured this increase in accrued carbon stocks in general, and specifically mineral associated stocks down to a meter depth. For TRS, we define permanence realistically, from the perspective of how the earth has performed, as a model for what can be accomplished, rather than from a theoretical legal perspective. Paleontological studies and carbon dating of soil organic carbon stocks in unglaciated landscapes (i.e. Palouse agroecosystem in Eastern Washington State) have average carbon ages in the upper 1 dm of 200-300 years. And, from 2 to 10 dm the average age is 200,000 years (Retallack 2007). In glaciated corn belt regions of WI, IL, IA the average age in the upper 1 dm is 200-300 years, and > 5000-7000 years below that to an ~ 1 m depth (Apfelbaum unpublished data using UM Pollen analysis). In New Mexico, near Corona, to 1 dm depth the age was ~1000 years; below 2 dms, the age was 3-5 million years (\_Monger 2014). A literature review is beyond the scope of the intent of this Glossary of terms. That said, a central valley CA study found topsoils had an average age of several hundred years and 1500-1800 years below that to 1 m depth.

**Achieving permanence is defined under TRS using three criteria learned from measuring Soil Organic Carbon to 1 m depth:**

1. Increased soil organic carbon deeper in the soil
2. Increased mineral associated carbon fractions
3. Reduction in relative abundance of shorter-lived particulate carbon fractions

**Permanence Period:** TRS requires annual monitoring and reporting during each year a parcel is enrolled under the TRS SOC. TRS also requires project end monitoring when the enrollment true-up resampling and measurement of soil organic stocks are measured and compared with the baseline measurements to document accruals that have occurred. After enrollment ends, for a period of forty years, annual monitoring and t0th year monitoring close out documentation is required to be delivered to TRS by the project proponent. The monitoring reports shall be focused exclusively to document compliance with maintaining the activity change that was executed on each the property. Permanence monitoring and documentation can be accomplished using remote sensing with on-the-ground confirmation photography.

**Planned:** Changes in the value of the variable are under the control of identified agents who are independent of the Project Proponent.

**Post-Crediting Monitoring Period:** After the crediting period for each project, monitoring for reversals begins. The duration of this period, by election of the project developer, shall be a minimum of 40 years, and a developer shall elect this minimum period, or other options that include 100 or more, including a perpetual commitment to annual monitoring to ensure reversals do not occur.

**Project Boundary (See Enrolled Property Boundary)**

The area or areas of land on which the Project Proponent will undertake the project activities. TRS SOC defines a project as any group of properties, where upon, a similar project activity is proposed, that enroll to participate by use of TRS SOC, that occur in a USDA (or equivalent) defined Major Land Resources Area within the defined period of time around which the project is organized, as submitted in the PDD, and approved through the verification process. Across the USA, there are Major Land Resources Areas (USDA, NRCS 2022) (MLRA’s) defined based on biophysical conditions present, and for each a description of the typical land use history, including land settlement and cropping and soil tillage activities are provided.

One or more projects proposing the same project activity change can be defined within each MLRA by different carbon project aggregators/developers. And, one or more projects can be defined for other activity changes within the same MLRA’s.

Where MLRA’s are not defined (such as outside the USA), ecoregional and agroecoregions, and biome definitions may be offered as biophysical boundaries that can be reviewed by The Regenerative Standard as acceptable congeners to the MLRA definition. Examples of ecoregion definitions occurring outside the USA as defined by Walter 1983 can be considered for use in providing high level understandings of a project’s biophysical setting.

As an example, an improved grazing project found in a single mapped MLRA in central Montana; this single MLRA (like many others) occupies very large acreages of land. Many ranches can be considered part of a single project if they sign up for participation of improved grazing as the activity, within the time period for this improved grazing offering.

To meet the project definition, Carbon project developers must document the MLRA of each ranch and then give each project a unique nomenclature (which should be informed by the biophysical stratification conducted for each participating property), to specify the activity and time period of the project. This must be denoted in the PDD.

**Project Design Document (PDD) or “Project Plan”:** A carbon project developer creates a PDD for submittal to The Regenerative Standard, a third party Verifier, and Nature’s Registry. The PDD contains all document requirements under the Project Framework. See “**Project Registration, Verification and Validation” definition.**

**Project Proponent:** The individual or organization that has overall control and responsibility for the project, or an individual or organization that together with others, each of which is also a Project Proponent, has overall control or responsibility for the project. The entity(s) that can demonstrate project ownership in respect of the project.

**Project Life Span:** The time over which the soil carbon project generates and accounts for carbon credits. Because of varying time periods for soil carbon change statistical signals (See Expected Time Increments definition), the life span will vary. Overall project life span may last for decades, the time required to regenerate and restore carbons stocks from deteriorated state (see USDA 2014 documentation of 70-90% deterioration on average across the USA).

**Project Registration, Verification and Validation:** The process of submitting the full required documentation, which may include an “Idea Note” for a pre-application conference with the registry and verifier, or the fully required submittals: “The Project Design Document (PDD) ”, The Measurement and Monitoring Plan”, The Verification Report, The Validation Report, and other required documentation by the carbon project developer to Nature’s Registry. The Verifier/validator is required for registering, and formalizing verification/validation, and all record keeping, credit certification and issuance by the Registry. Requirements for submittals are detailed in TRS SOC V2.0 and in the Verification checklists.

**Project Verification Period:** The time between project initiation and each crediting event. Under TRS SOC V2.0, carbon project developers can verify annually and credit annually, and under this scenario the Project Verification Period is annual.

**Project Scenario:** The resulting soil carbon pools over the project time due to the project activity. The soil organic carbon stocks are present at the next scheduled soil measurement date, calculated according to the technical procedures and methods described below. For example, a project that plans to conduct soil measurements every five years, the initial (T0) measurements are taken in year zero and the project scenario measurements are taken in years five (T1), ten (T2), fifteen (T3), and so on.

**Project Start Date**: The first field sampling date for any Project, also annotated as Time Zero or “T0.”

**Project:**

TRS and Nature’s Registry consider a “project" as a single property being entered into a carbon sequestration program. In certain circumstances, several properties can be aggregated together to be registered simultaneously by Nature’s Registry as a single “project” as long as all have the same project activity for which credits are generated.  Said properties can be identified by having different ownership, lease holdership, geography under the same project activity, and same vintage, as long as they are able to be treated as one entity for review, verification and validation. No more than 10,000 acres can be aggregated together in this way under a single project designation.

**Reduced GHG Emissions and Crediting**: Practice changes (except for land protection-see Avoided Conversion definition) directly resulting in a reduction in GHG emissions, such as by reduced tillage, or reduced or eliminated fertilizer use.

**Registry Checklist**: Clear, step by step registry procedures to be followed by “Nature’s Registry” (or other) to ensure the Registry follows a standardized, rigorous process for verification reports, in reaching certification and credit issuance decisions.

**Removal**: Carbon stocks that are comprised of highly recalcitrant fractions of organic and mineralized carbon such as fire pyrolyzed carbon (char), submerged and saturate carbon protected from oxidative and anerobic decomposition because of the chemical environment (e.g. pocosin peat protection by antimicrobial/antifungal phenolic compounds, etc.), mineralized forms of organic carbon (e.g. mineral associated organic carbon fractions) comprise forms of carbon that may be stable for predictable long periods of times, measured on geological time scales of thousands to millions of years.

**Significant:** A pool or source is significant if it does not meet the criteria for being deemed de minimis. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project.

**Soil:** Soils are typically defined as the upper layer of earth in which plants grow, a black or dark brown material typically comprising of a mixture of organic remains, silt, clay and sand in various percentages which define the type of soil. For purposes of the TRS SOC, soils are defined as inorganic, mineral, and organic soils. Inorganic and mineral soil types can contain organic matter. Soils of each type, except hemic and fibric peat soil types are able to be included under this method when measurement to measurement soil sampling documents an increase in soil organic carbon stocks. Soils with a hystic epipedon, may also be included if the hydrology and wildfire/prescribed burning regimes that may be associated with land management activity do not degrade, decompose, erode, of combust the hystic epipedon.

**Soil sampling depth of refusal:** during soil sampling, this is the depth at which, for example, bedrock, scattered rocks, or tree roots prevent achieving deeper sampling of soils. This depth is recorded if it falls short of the 1-meter sampling depth requirement under TRS SOC.

**Stratification:** The division of an area into sub-units (strata) which are homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could be expected to be similarly identified and classified by different people.

**Static Baseline:** is a base with an unchanging trend that may fluctuate around a mean rate. This is different than a constant baseline which may have a constant declining or increasing trend, a rate of change that does not change and assumes a trajectory that varies from a static baseline’s fluctuate around a consistent mean rate of change.

**Statum:** An area of land within which the value of a variable, and the processes leading to a change in that variable, are homogenous.

**Stratification:** Use of spatial data to evaluate and map biophysical conditions, including but not limited to: land-use history, geology, hydrology, cropping and grazing history, depth to bedrock, depth to water table (piezometric surface), land-use and land-cover, historic and existing vegetation, topography, slope, aspect, slope position, presettlement ecosystem mapping, flood prone, floodplain, paddocks or field identification and changes over time, historic cropping, soil types, soil textures, and myriad other data that may be available or procured for property.

**Stratified-Random Sampling**: Use of the stratification results to randomly allocate “random-stratified” sampling locations to statistically represent the varied conditions (strata) present on property, such as for the measurement of soil carbon on a landscape.

**Technologies:** New orimproved methods, tools, and processes that have well documented benefits for improved accuracy, precision, efficacy, and efficiency in the measurement (including analytical soil laboratory processes), computational needs, or automated documentation preparation, among other examples.

**Uncertainty:** Uncertainty is a parameter associated with the result of a measurement that characterizes the dispersion of the values that could be attributed to the measured amount.

**Validation:** The independent assessment of the project by a validation/verification body that determines whether the project conforms with the TRS SOC rules and evaluates the reasonableness of assumptions, limitations, and methods that support a claim about the outcome of future activities

**Validation/Verification Body (VVB):** An organization qualified to act as a validation/verification body in respect of providing validation and/or verification services in accordance with the TRS SOC rules.

**VCC(s):** Verified Carbon Credits are the currency of issuance of carbon credits used by Nature’s Registry. One VCC is equal to 1 TCo2e/acre and 1 TCo2e/acre-yr.

**Verification Date:** A date on which an independent verifier audits the results of monitoring.

**Verification:** The independent assessment by a validation/verification body of the GHG emission reductions and removals that have occurred because of the project during the monitoring period. The assessment is submitted to a registry that is independent from the Project Proponent and the verifier and is based on historical data and information to determine whether the claim is materially correct, conforms with specified requirements, and is conducted in accordance with TRS SOC rules.

**Verification Checklist:** Clear, step by step verification procedures to be followed by a prequalified verifier, which starts the verification process by evaluation of project submittal completeness.

**Verified Carbon Credits:** TRS SOC recognized unit of carbon currency is a Verified Carbon Credit (VCC), equal to 1 (one) Tonne of CO2equivalent.

**Vintage:** Refers to the date (typically the year) over which credits have been created for the market.

**Vintage Tracking:** Nature’s Registry records the project application enrollment date, validation date, verification date, and tracks transactions, credit vintages, and credit issuance by calendar year in the Registry ledger.

**Woody Biomass:** Biomass that exists primarily in the form of lignified tissues, such as that of shrubs and trees. Typically accounting of woody biomass includes the non-woody parts (leaves, etc.) of plants that contain woody biomass.

**Wetland:** Land that (1) has a predominance of hydric soils; (2) is inundate or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions; and (3) under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. This definition (US Army Corps of Engineers, 1987) has been developed pursuant to the Clean Water Act, Section 404 Definitions. This same definition is used with some language changes by the USEPA and the USDA, NRCS, with their definition applicable to croplands.

**Wetland, Seasonally Inundated:** Land that meets the definition of wetland that may occur in floodways, floodplains, shallow poorly drained depressional landscape position and in undrained farmed soils. Seasonally inundated inorganic and non-hystic soil dominated seasonally flooded land can be eligible for soil carbon crediting under TRS SOC.

**Wetland, Prior Converted:** Land that was historic wetland that have experienced altered hydrology from land drainage (such as the tiling or ditching) and altered vegetation systems, where the drainage alterations restrict a normal growing season prevalence of hydrophytic vegetation. Prior convere inorganic and non-hystic soil dominated seasonally flooded land can be eligible for soil carbon crediting under TRS SOC.

**Acronyms Used in TRS SOC V2.0**

| **Acronym** | **Meaning** |
| --- | --- |
| AFOLU | Agriculture, Forestry and Other Land Use |
| ARS | Agricultural Research Service |
| CDM | Clean Development Mechanism |
| CH4 | Methane |
| CO2 | Carbon Dioxide |
| FAO | Food and Agriculture Organization |
| GHG | Greenhouse Gas |
| IGM | Improved Grassland Management |
| ICM | Improved Cropland Management |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| N2O | Nitrous Oxide |
| NRCS | Natural Resources Conservation Service |
| PDD | Project Design Document |
| SOC | Soil Organic Carbon |
| T0 | Time Zero (initial sample date) |
| T1 | Time One (subsequent sample date) |
| UNFCCC | United Nations Framework Convention on Climate Change |
| VCS | Verified Carbon Standard |
| VVB | Validation/Verification Body |

# Project Framework

Project Proponent and Verifiers interested in working with TRS SOC V2.0 should consult with Nature’s Registry for Project Proponent and Verifier pre-qualification processes and requirements.

The project crediting period is at least five (5) years with a minimum forty-year storage requirement for each credit year and can be renewed an unlimited number of times, as supported by measure-to-measure improvements on the land. This project period minimum aims to incentivize more land regeneration from Land Stewards resistant to traditional 100-year requirements but who want to engage in ecologically valuable projects. Verification period is required to coincide with each credit release, and the crediting timeline is identified by the applicant. Both the verification and crediting timelines can be annualized, but both must proceed on the same timelines. The proponents proposed timeline dictates both, with the true-up timing occurring during the estimate range in years between T-0 and T-1 (e.g. 5-7 yrs.) as described above, from what has been learned about the time required under various regenerative practices in different ecological/geographic settings to be able to accurately measure a statistical signal of changes in soil carbon stocks (*See literature references in TRS-Soil Carbon Method modules*).

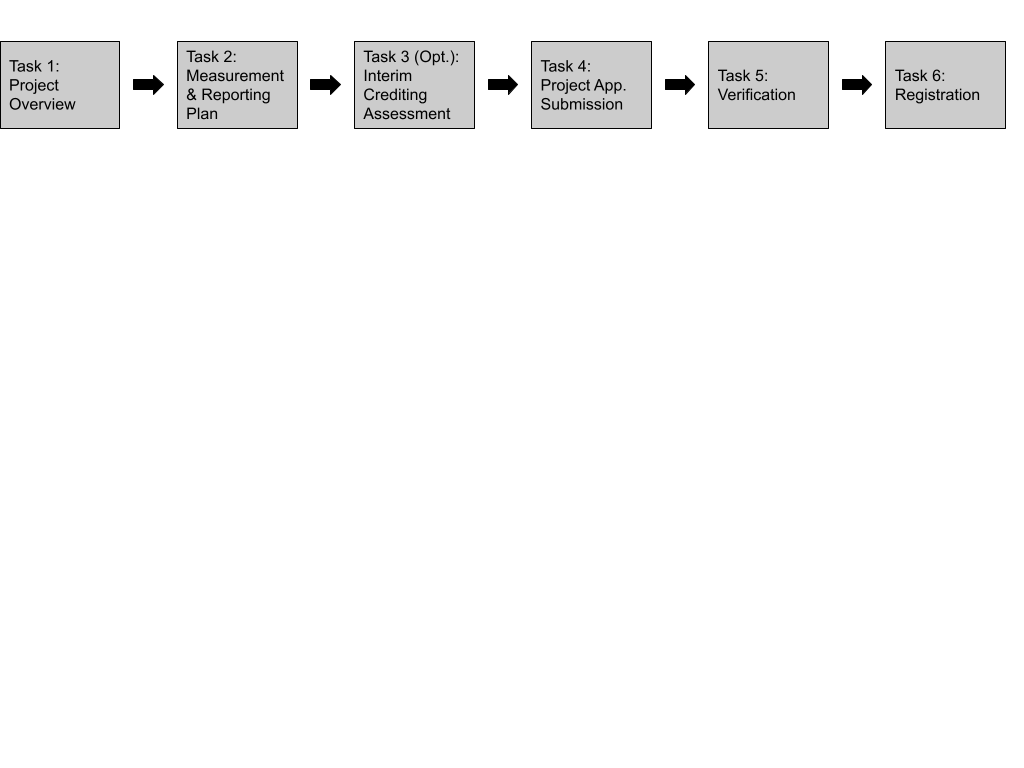
The project start date is defined as the date of commencement of the initial (T0) set of baseline soil measurements. The project start date can be up to five (5) years prior to the project registration date if the T0 sampling measurements are consistent with this TRS SOC V2.0.

Credit yield shall be calculated as the project scenario; the soil carbon measured in the project area after conversion to regenerative practices minus the soil carbon measured at the time of the baseline sampling.

Project registration and validation is required of an approved Project Proponent by the submittal of a Project Idea Note to an approved verifier and Nature’s Registry\*\* for any project proposed under TRS SOC.   
\*\*Nature’s Registry is a separately governed and administered organization from The Regenerative Standard, and is addressed outside of this TRS-Soil Carbon Method document.

For project qualification and the issuance of credits, both interim and final, TRS SOC requires the Project Proponent to complete the following tasks (**Figure 1**) each of which is comprised of a number of sub-tasks:

* Task 1: Project Overview - Identification and Eligibility of Project Activity
* Task 2: Measurement and Reporting Plan
* Task 3: Interim Crediting Assessment (optional)
* Task 4: Project Application Submission
* Task 5: Verification
* Task 6: Registration



**Figure 1. Overview of project framework and documentation**

Additional details are provided under the respective tasks’ sections in TRS SOC V2.0.

# Project Requirements

When completing a TRS SOC Project Application, a Project Proponent shall submit responses to the following:

## Project Overview - Identification and Eligibility of Project Activity

A Project Proponent should summarize the land management activities, the stratification process and stratified-random sampling plan proposed, how data is collected, literature sources that support the project, planned project activities, and any deviations or additions to the methodologies detailed and/or referenced under TRS SOC. The project proponent must also demonstrate proof of contract with the land steward(s) as a submittal requirement, confirmed and affirmed by the verification and registry certification processes.

The longer-term roadmap for The Regenerative Standard is to layer in complexity over time. Phase 1 of the release of TRS is focused on The Soil Carbon Measurement Method (TRS SOC). Phase 2 will add Biodiversity. TRS SOC is focused on cropland, grassland and conservation/restoration project soil carbon. Future phases will integrate carbon stock changes in forests, wetlands, and peatlands. The soon to be introduced Biodiversity Method cuts across all ecosystems and land uses, and crediting is anticipated to be an option for additive credit with TRS SOC V2.0-based credits.

### Data confidentiality statement

A Project Proponent should list any data that is to remain confidential between the Project Proponent, Verifier, and Registry. Such data includes personal data, addresses, data related to the project properties, historical, current, and future land management techniques, livestock information, ecological assessment data, etc.

While data confidentiality is honored and necessary, data sharing under terms of protection and confidentiality is also encouraged to foster the exchange of knowledge essential to accelerate scaling, adoption, and to refine decision making so that time is not wasted experimenting with “what if” strategies for improving carbon drawdown and re-growing soil carbon stocks.

TRS SOC requires that raw data, computations, mapping of project baseline and responses to management to be submitted to the verifier for the verification process and with Nature’s Registry for credit certification, issuance, and warehousing. We are exploring confidential data warehousing for participating carbon project developers so that meta-analyses, such crowd sourced real time national mapping of carbon stocks and accrual rates can benefit all carbon developers. This can help reduce the discounting on credit yields, by providing more accurate early estimates of carbon credit yields, and other benefits. Actual landowner georeferenced data would be anonymized and confidential.

Carbon program/project developers are requested to discuss their willingness to explore participation in this data sharing and meta-analysis and having confidential web-portal access to updated findings created though this partnering. This broader philosophy can benefit all developers and accelerate rapid scaling of solutions to address soil carbon stock improvements, biodiversity, and other benefits of The Regenerative Standard.

### Physical Address of the Properties Submitted for Certification

A Project Proponent should describe the location of the project property with an address, latitude, longitude, total land area (e.g., acres, hectares, etc.), creditable land area, and verification of ownership (e.g., tax assessors’ data and vesting deed(s)).

### Description of Land Management Activity

A Project Proponent should document and describe landowners’ historical, current, and planned future land management practices, as applicable:

* type(s) of livestock
* stocking rates
* number and size of paddocks
* average rest and recovery periods
* average rotation frequency
* forage information
* mowing/bush hog
* bale grazing.
* chemical usage
* compost usage
* notable wildlife/plants
* notable non-native wildlife/plants
* crops/crop types
* burning
* termite and earthworm diversity/density
* soil organism’s genomics census
* cover crop activities
* other relevant and notable agricultural practices

For grazing projects, land management should be assessed semi-qualitatively using multiple factors that govern success in soil restoration using grazing, including:

* land management style
* number of years of regenerative or holistic management practice
* # of paddocks
* average paddock size
* stocking density
* stocking numbers
* rotational frequency
* livestock and wildlife diversity
* grazing plan documentation
* specific individual holistic practices impacting soil health

This qualitative assessment may determine how closely the reported grazing practices can correlate to a high, medium, or low impact to the site conservative estimate of soil organic carbon accrual potential.

### Project Eligibility

TRS SOC V2.0 is intended for use by projects on agricultural, grazing, and other regenerative, restorative practices or conservation lands undergoing Land Use Activity Change. Planned and/or implemented land management practices must be incorporated in the project plan to ensure that the project will increase the actual measured storage of soil organic carbon within the boundaries of the project.

A Project Proponent should use this section to describe how a project meets either the mandatory or optional project eligibility criteria outlined below.

#### Mandatory Eligibility Conditions

All projects using this methodology must meet the following mandatory conditions:

* **Agricultural Land Management**Activities that increase carbon stocks in soils and non-forest woody biomass and reduce CO2, N2O and/or CH4 emissions to or from soils on croplands and/or grasslands. Avoided conversion projects are not eligible under TRS SOC V2.0 (See Glossary of terms) but projects that generate reduced GHG emissions may be eligible. And activities that   
  + Improved Cropland Management (ICM**\*\***)
  + Improved Grassland Management (IGM)
  + Cropland and Grassland Land-use Conversions (CGLC)

**\*\*** See acronyms in the Glossary of Definitions.

* **Grassland or Cropland**  
  As of the project start date all the project areas consist of grasslands or croplands or non-forest and non-wetland, non-peatland landscapes. Crops may include woody species grown for food products, fuel products, or timber, providing that the densities of these crops do not meet the definition of forest lands. Orchards that integrate improved practices (e.g., a conversion of annually tilled cropped land, such as between the rows of fruit or nut tree crops) to perennial grasses that measurably improve soil organic carbon is an example of a “non-forest, food cropland” a project type under TRS SOC. If improved grassland, cropland, and improved management of protected or restored land is not the primary acreage enrolled by a landowner, these can be “associated enrolled land”, if the eligibility requirements are met (See definition of Soil in glossary of terms).
* **Non-forest, Non-wetland, Non-peatlands**  
  The project area *must* exclude and must not have been had forest land cleared or, or wetlands or peatlands dewatered or filled in the past 10 years, with these types defined as:
* Forest: Land with woody vegetation that meets an internationally accepted definition (e.g., UNFCCC, FAO, or IPCC) of what constitutes a forest, which includes threshold parameters, such as minimum forest area, tree height, and level of crown cover, and may include mature, secondary, degraded, and wetland forests and may be multi-species or have a simple single species composition. (See definition of Forest in glossary of terms)
* Wetlands: Land that is inundated or saturated by water for all or part of the year (e.g., peatland), at such frequency and duration that under natural conditions they support organisms adapted to poorly aerated and/or saturated soil. Wetlands (including peatlands) cut across the different AFOLU categories. Project activities may be specific to wetlands or may be combined with other AFOLU activities. Periodic flooded croplands are only excluded if they are jurisdictional wetlands or farmed wetlands (as determined in the US Army Corp of Engineers 1987). Under this same manual, the USDA, NRCS focused their definition on agricultural lands, and their expanded program definitions include, *Prior Converted (historic wetlands) lands*, which can be included, if the conversion occurred prior to a decade before the proposed soil carbon project initiation date. They also define “*Jurisdictional wetlands”* which are excluded from this protocol only because the soil carbon measurement methods required for accurate repeated measurements are different than what is specified under TRS SOC. Wetland substrate carbon is also addressed in other protocols, for example addressing peat system carbon. (See definition of Wetland(s) in Glossary of Terms)
* Peatlands: An area with a layer of naturally accumulated organic material (peat) that meets an internationally accepted threshold (e.g., host country, FAO, or IPCC) for the depth of the peat layer and the percentage of organic material composition. Peat originates because of water saturation. Peat soil is either saturated with water for long periods or artificially drained. Common names for peatland include mire, bog, fen, moor, muskeg, pocosin, and peat swamp (forest). Peatlands are only excluded if they are jurisdictional wetlands or farmed wetlands (as determined in the USA by the 1987 US Army Corp of Engineers, Wetland Delineation manual, and regional updates). Peatlands are excluded because the soil carbon measurement methods required for accurate repeated measurements are different than what is specified under TRS SOC and have been specifically addressed in other protocols. (See Peat land definition in the Glossary of Terms).
* **Displaced**  
  The only baseline activities that could be displaced by the project activities are grazing and fodder production, crop production, and timber production. For example, continuous grazing can be displaced by improved grazing, such as adaptive multi paddock grazing to contribute to significant soil carbon improvements and predicted climate mitigation benefits (Teague et al 2016). Or, fodder production and crop production could be displaced by improved cropping, such as conversion of annual fodder to perennial crops (USDA 2014, Kimble et al 2007), or timber production that emphasizes understory vegetation health and productivity as a part of timber production, such as during oak savanna restoration (Apfelbaum and Haney 2010 and 2012).
* **Soil Water Regime Changes**  
  Project activities *must not* include changes in surface and shallow (<1m) soil water regimes through flood irrigation, drainage, or other significant anthropogenic changes in the groundwater table.
* **Termites**  
  The project activity *must not* cause a significant change in termite populations, as compared with the baseline scenario. The consideration of termites in a soil carbon project is primarily focused in tropical and subtropical grasslands and savannas. Termites exemplify one of a group of organism types that can contribute to significant improvements in primary productivity on a landscape, such as in subtropical grasslands and savannas (Whittaker R. H. 1979) but a significant increase in their abundance can result in methane emissions that can exceed the soil organic carbon improvements. The measurement (mapping of locations and enumeration the number) of terminaria as a part of baseline sampling and during annual monitoring and reporting, and for the true-up monitoring period, would need to show insignificant increases in the number of terminaria as a requirement to demonstrate eligibility during a project and crediting period.

#### Optional Eligibility Criteria

The following conditions do not need to be met to utilize the methodology. The consequence of meeting these eligibility requirements for these conditions is that this allows the simplification of the methodology through the elimination of the requirement for the completion of specific tasks. The Optional Eligibility Criteria are available when a “representation or findings” of “No Change” for a baseline measurement(s) can be conservatively used to document no change in GHG emissions are expected even though an unequivocal decrease under the activity change is well documented (under a common activity change) or can be demonstrated. Use of the “no-change” selection, with a focus on measurement to measurement soil carbon stocks may be exercised by the project proponent. A project developer may also choose to formalize in their PDD, and measurements of actual Reduced emissions, and substantiate crediting for this GHG reduction. The following are examples of how this optional eligibility can be opted/opted out with the “no-change” option under TRS SOC.

As an example, a carbon project developer may opt to conservatively assume that actual GHG emissions before and after a conversion from an annually tilled farm field to a perennial native grassland are the same. By opting to use this assumption, they could use scientific literature GHG emissions profiles for any documentation needs, or all together assume no change occurs. The option of not measuring or projecting the changes can only be used where the scientific literature provides clear certainty that GHG emissions decrease with the changed land use or activity. Eliminating specific measurement or documentation tasks can be justified where project/program conservativeness is justifiably enhanced.   
  
*Consequence if met*: Project Proponent *is not* required to complete [*Task 2.3.7 Projection of future emissions of N2O or CH4 from the soils within the project area*](#bookmark=id.bcfcowpc6n8n) and [*Task 2.3.26 Monitoring and estimation of soil emissions of N2O or CH4 from within the project area*](#bookmark=id.anfoiaq2jfwd) described herein.

* **Degrading Baseline Scenario (can be recognized as a type of dynamic baseline)**  
  The activities and agents which have caused the degradation of the croplands, grasslands, rangelands, and conservation lands and their soils are expected to continue to impact the area in the absence of the project activity. On that basis, it can be demonstrated that soil organic (and often inorganic) carbon stocks in the project area are highly unlikely to increase under the baseline scenario during the project crediting period.
* Protocols that refer to a Degrading (changing by loss of soil organic carbon stocks) baseline as a **Dynamic Baseline** (which vary over time with a declining trajectory in mean soil organic stock levels) contrast with a stable baseline (which vary temporally around a “stable” mean soil organic stock level) may or may not account for the dynamics at a landscape scale. Many projects that have used dynamic baselines have been project specific focusing on a narrowly defined type of activity. However, when working with large landscapes with a diversity of land use and changed land use activities, a “common activity baseline” or “weighted baselines” have been used to understand each participating property’s baseline and its likely trajectory within the larger statistical landscape.
* For clarification, many existing agricultural, rangeland, and even conservation land conditions are declining. If a carbon program developer chooses to develop a “common activity baseline” for the region over which their improved agricultural soil carbon project is proposed, this could for example represent declining soil organic carbon stocks, using the weighted average loss based on the acreage of moldboard plowing (~2 TCo2e/acre per yr.), & conservation tillage (Loss of ~1.7 TCo2/acre-yr.), and one pass no-till ( + 2 TCo2e/acre-yr.) to mathematically estimate the regional losses as the baseline against which project site future project activities can be judged; this is the process used in Apfelbaum et al (2022). Or, the project proponent may conservatively assume no change would have occurred on the properties included in the project if the improvements under the proposed activity change did not occur.  
    
  ***Consequence if met*:**

If a project proponent can justify the selection of no-change under **Tasks 2.3.2** through Tasks **2.3.10**, then this would be so noted in their PDD. This selection would only require that during the project crediting period, during annual reporting and the true-up verification and crediting period, that documentation must be provided to affirm and defend this selection of “no-change”.

A second decision that must be documented is the use of a “stable” vs a “common activity baseline”. Generally, a stable baseline is more conservation, while a common activity baseline can more accurately document overall net changes in carbon accounting over the regional context, it can also be more challenging to measure and calculate in a robust and defensible way.

Given this additional complexity, a proponent in their PDD may also elect to use “a stable baseline”, which for purposes of TRS-Soil Carbon Method would be the equivalent of selecting the “No-Change” option. This is explained below:

* Project Proponent may conservatively use a “Stable or Static Baseline Estimate”: by assuming that soil carbon content for all future dates under the baseline scenario shall be accounted as equal to the current soil carbon content, subject to re-assessment at true-up (T1, T2, etc.), as required under TRS SOC V2.0.
* Optionally, a proponent may choose to create their property specific/land use history specific baseline measurements and then also create a “common activity baseline” so that accurate carbon accounting can be done to document the net changes/improvements by measurement to measurement changes on the project site, but also embed those changes within a landscape understanding.
* Using the above for example, the “Stable baseline” based on Chronoseries analysis and confirmed with repeat sampling and also with flux tower analysis (the difference in carbon stocks between T-one minus T-zero levels, and over the same period of time--total mass balance Flux tower measured Total C sequestered) documented a + 2TCo2e/acre-yr. soil organic carbon accrual. But, the total net improvement using the “Common Activity Baseline” would include the gain under the Stable Baseline + the Reduced Emission losses of an additional ~ 2 Tco2e/acre-yr. based on common activity baseline. Thus the net change over the study region of 7 million acres with the conversion to Low Disturbance Cropping (with other performance details (See Apfelbaum et al 2022) was ~ 4 TCo2e/acre-yr.
* **No Change in Above and Below-Ground Biomass**  
  Changes in above and below-ground living biomass pools within the project area can be shown to be insignificant under either the baseline or project scenarios.   
    
  *Consequence if met*: Project Proponent *is not* required to complete [*Task 2.2.1 Project area stratification for biomass*](#bookmark=kix.dklrz4lamkmc), [*Task 2.2.2 Estimation of the carbon content of current above-ground woody and non-woody biomass and below-ground living biomass pools*](#bookmark=kix.hs5cqzxds4dm), [*Task 2.2.3 Projection of future biomass pools under the baseline scenario*](#bookmark=kix.hcxrjy99mdxo), and [*Task 2.4.2 Estimation of the carbon content of above-ground woody and non-woody and below-ground living biomass pools*](#bookmark=id.qlciy9lb6mp) described herein.
* **No Change in Woody Biomass**  
  Woody biomass is found within the project area but amounts of current and projected wood harvest under the baseline and project scenarios are not significant.   
    
  *Consequence if met*: Project Proponent *is not* required to complete [*Task 2.4.3 Estimation of the amount of wood harvest from within the project area used for the production of long-lived wood products*](#bookmark=id.eha5ml8c0o18), and [*Task 2.4.4 Long-lived wood products*](#bookmark=id.sqpn8lceyofk) described herein.
* **No Change in Fertilizer, Manure, N-fixing Species. Flooding**No significant change is expected to occur in the amounts or locations of any of the following conditions or activities between the baseline scenario and the project scenario:   
  + Amount or location of application of organic or inorganic fertilizers.
  + Amount or location of domesticated animal grazing and deposition of manure or urine.
  + Amount or location of areas subject to flooding, and duration of flooding.
  + Amount or location of nitrogen-fixing species.

### Project Boundary

A Project Proponent should identify the project boundary using the module [TRS-3 *Methods to Determine Project Boundary*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0020-Methods-to-Determine-Project-Boundaries-v1.0.pdf), noting exclusion areas, project start date, and project end date. Providing the project boundary as KML files or other interconvertible formats (e.g., geodetic polygons, additional shape files, maps, .kml files, GPS coordinates, etc.) to support the identification of boundaries accurately and unambiguously is required. The Project Proponent should complete the following task to identify the project boundary:

#### Identification of project boundary

|  |  |
| --- | --- |
| Requirement | Required for all projects. |
| Goal | To determine the project boundary for baseline scenario and additionality purposes. |
| Method | Determine the project boundary using the module [TRS-3](https://verra.org/wp-content/uploads/imported/methodologies/VMD0020-Methods-to-Determine-Project-Boundaries-v1.0.pdf) *[Methods to Determine Project Boundary](https://verra.org/wp-content/uploads/imported/methodologies/VMD0020-Methods-to-Determine-Project-Boundaries-v1.0.pdf)* |
| Comments |  |

### Baseline Scenario

This Task furthers the scrutiny in defining your baseline, and subtasks under Task 2 provide a framework for evaluating and documenting how you construct a baseline scenario for a project. Details on stratification, estimation of existing and future soil carbon stocks are detailed in [TRS-1](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/) *[Methods to Determine Stratification, v1.0](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/),* [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions, v1.0](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf),* [TRS-3](https://verra.org/wp-content/uploads/imported/methodologies/VMD0020-Methods-to-Determine-Project-Boundaries-v1.0.pdf) *[Methods to Determine the Project Boundary, v1.0](https://verra.org/wp-content/uploads/imported/methodologies/VMD0020-Methods-to-Determine-Project-Boundaries-v1.0.pdf) and* [VMD0021\*\*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf) *[Estimation of Stocks in the Soil Carbon Pool, v1.0](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf). Computations for documentation.* Details to develop a monitoring plan to measure baseline and the re-measurement of soil carbon stocks ([TRS-16](https://verra.org/wp-content/uploads/imported/methodologies/VMD0034-Methods-for-Developing-a-Monitoring-Plan-v1.0.pdf) *[Methods for Developing a Monitoring Plan, v1.0](https://verra.org/wp-content/uploads/imported/methodologies/VMD0034-Methods-for-Developing-a-Monitoring-Plan-v1.0.pdf))* and computations to document measure to measure changes in stocks (and including net changes if GHG emissions reductions are opted to be addressed by a carbon project developer), are provided ([TRS-17](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities, v1.0](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf)).*

A Project Proponent should follow the Baseline Scenario instructions in accordance with the information in *[Task 1.4](#bookmark=id.xyuc7aflfaxp)**[Project Eligibility](#bookmark=id.xyuc7aflfaxp)* and the above detailed technical methods, and for a project that meets the conditions in *[Task 1.4.2 Optional Eligibility Criteria](#bookmark=id.keriid1hd44d).* A Project Proponent should describe which criteria are met and list any credible references, as applicable.

The **baseline scenario**, which is what is actually measured, is the quantity of soil organic carbon present in the project area resulting from business-as-usual management practices. For TRS, the measured soil organic carbon stocks across a project site, that have been measured following the stratification, random sample allocation and numbers, and that have achieved defined sampling statistical sufficiently are used by the project proponent to document carbon stocks under an assumed to be static (i.e.. constant) activity during the project period.

TRS requires 1-meter-deep soil sampling (or to refusal, See glossary of terms) to establish a project T0 baseline. Using this actual measurement and assuming a static baseline scenario is more conservative since only atmospheric CO2 removals, (unless a carbon project developer chooses to address both removals and emission reductions), are quantified for additionality and crediting in TRS. Emission reductions might realistically occur, but due to the challenges and uncertainties of characterizing dynamic baselines at a landscape scale, a much more conservative static baseline minimizes the uncertainties by assuming no change in soil carbon stocks resulting as thought existing land uses continued. This assumption thus accepts measured changes over time in Soil organic carbon levels compared to the baseline level measured under the continued land use. And, after remeasurement during Time-one accepts that all changes from the baseline measurement would result from the change in activity during the project period.

While a static baseline (See definition of Static baseline) is possible, it is also a conservative assumption because in most conventionally managed agricultural and continuously grazed rangelands, and conserved lands that are not managed, the baseline measured soil organic carbon stocks often decrease in the absence of a regenerative/restorative project activity (as per [*Task 1.4.2 Optional Eligibility Criteria*](#bookmark=id.keriid1hd44d) described in the previous section). As an example, for conventional continuous and long rotation/short (or no) recovery rotational grazed landscapes, declining carbon stocks have been well documented (Teague et al,2011, 2016; Sanderson et al 2020, etc.). conventional row crop lands. Similar findings for soil organic carbon declines have been documented for conventionally tilled and row cropped farm ground (Kimbal et al 2009). In overgrazed properties, soil degradation stemming from the deleterious consequences of forage consumption exceeding forage production ([Sanderson et al. 2020](https://www.jswconline.org/content/jswc/75/1/5A.full.pdf)) is particularly well documented as causative. In protected conservation land that are not being managed (e.g. fire suppression of fire-evolved and maintain grassland, savanna, wetland, forests) while aggressive and productive non-native and invasive shallow rooted and often annual plant species may increase above ground biomass, the below ground soil carbon stocks also have been documented to decline (Kimble et al 2007, Follett 2001, Folley et al 2005, Apfelbaum et al 2022).

While baseline is measured first and foremost, in terms of carbon stocks present, the project proponent also must provide fundamental measures of ecosystem integrity. This can be done using some standard simple measures such as for land cover, plant species composition, bare soil, presence/abundance of non-native invasive plants, etc. (See standard procedures and data collection forms in Apfelbaum and Haney 2012, The Restoring Ecological Health to Your Land Workbook, Island Press) which can provide for the measurement and understanding secondary evidence (Soil carbon stock measurements are the primary evidence) of the condition(s) occurring on the land before the activity change (i.e. at the time of baseline sampling) and after activity change (i.e. Time-one, Time-two…) the change in activity occurred.

Depending on project site complexity, there are many other ways to add additional levels of details, such as examination of historic and existing conditions. Additional understandings, besides just having carbon stock levels will not only contribute to the understanding of how the land (and carbon stocks change over time) but also can affirm over time that the baseline selection was defensible.

A conservative approach, a static baseline (See glossary of terms) must still be evidenced through demonstration of minimal water and wind-borne soil erosion (e.g., UNFCCC/CCNUCC - Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities). Such evidence can be provided by measured percent bare soil, perennial vegetation plant cover, and/or invasive and non-native plant species percent cover using on-ground sampling and/or multi-temporal aerial photography or remote sensing which demonstrate the establishment of persistent vegetation cover for consecutive years, particularly following management conversion in degraded lands where re-establishment of healthy, diverse and productive plant communities can take many years. The baseline is established with a site visit evaluating strata, vegetation, and sampling to 1-meter deep and the results of the sampling event and other data collected during T0 represent the “best estimate” of the actual site baseline.

TRS SOC V2.0 allows static baseline and other scenarios at the option of the carbon project developer. Further details on baseline scenarios, and how to assess and frame the baseline to accomplish the requirements of this methodology; associated required submittals are elaborated under Task 2 and subtasks.

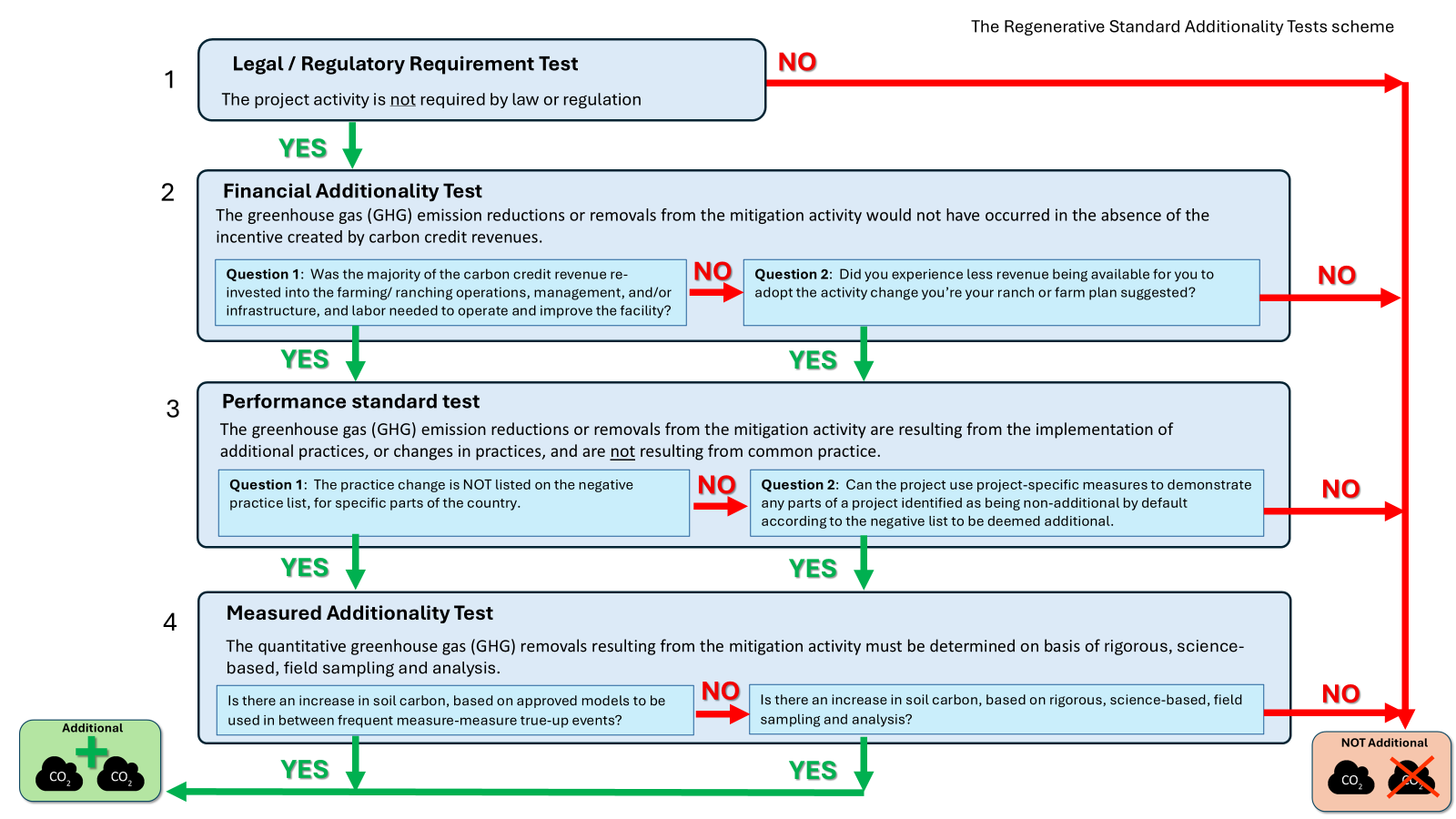
### Additionality

**Additionality Testing Requirements**

**Introduction**  
The Regenerative Standard (TRS) aims to deliver the highest quality nature-based carbon removal credits. It is important for most carbon credit buyers that the acquired credits meet rigorous additionality criteria. TRS SOC V2.0 has adopted an expanded and transparent framework of rigorous and pragmatic best practices to ensure that TRS credits are considered fully additional.

In short, credits are additional if the GHG removal would not have happened in a “business as usual” situation. Project proponents must demonstrate additionality by passing all 4 rigorous tests:

1. **Legal / Regulatory Requirement Test** - The project activity is not required by law or regulation.
2. **Financial Additionality Test** - The greenhouse gas (GHG) emission reductions or removals from the mitigation activity would not have occurred in the absence of the incentive created by carbon credit revenues.
3. **Performance Standard Test** - The greenhouse gas (GHG) emission reductions or removals from the mitigation activity are resulting from the implementation of additional practices, or changes in practices, and are not resulting from common practice.
4. **Measured Additionality Test** - The quantitative greenhouse gas (GHG) removals resulting from the mitigation activity must be determined on basis of rigorous, science-based, field sampling and analysis.

Additionality is important to determining your use of The Regenerative Standard (TRS). The supposition is that if your project fails any one of the four tests, then the reduced carbon drawdown impact, or in this case improvements in measured soil carbon quantities in the ground, are not to be made available for sale in the carbon markets. TRS SOC V2.0 requires four rigorous tests of additionally. All four of the tests must be applied each time carbon credits are generated with expectations that the credits would be for sale in a voluntary or compliance marketplace. However, we recognize that for two of these tests—financial and measured additionality tests—the long-term and reliable answer may not be known for several years. Because of this, we define details for each additionality test as follows: 

1. **Legal/Regulatory Requirement Test  
   Objective:**   
   To determine that the project activity is not required by law or regulation.  
    **Evidence to be provided:**This test has an applicant (with verifier confirmation) documenting if the project activity change (e.g. a grazing change, planting a crop conversion, or converting from one method of tillage to another, etc.) is required by a legal decree, a zoning or regulatory permit or ordinance, law or regulation, agency approved farm/ranch plan or enrolled program. If the answer is NO, then your project has passed this test of additionality.
2. **Financial Additionality Test  
   Objective:**   
   To determine that the greenhouse gas (GHG) removals from the mitigation activity would not have occurred in the absence of the incentive created by carbon credit revenues.

**Evidence to be provided:**  
This test has an applicant (with verifier confirmation) documenting if the project activity change could only be successfully implemented if the financial remuneration from selling carbon credits was available to the project. The applicant is required to determine if a carbon transaction is required, or is projected to provide the financing required before the applicant can afford to implement the practice change at scale (e.g. a grazing change, planting a crop conversion, or converting from one method of tillage to another, etc.) At scale means the practice change would be implemented at a sufficiently large enough scale over the acreage of land in your plan.

If you happened to already have adopted or experimented with the same practice change, you are considered as an “early adopter” and under most standards this has been used as evidence that the carbon financing was not needed for you to make the change.

What we have learned by working with farmers and ranchers is that even if you are an early adopter, most early adoption involves a steep and many-year learning curve to changing practices and making equipment changes. Because of this, most early adopters remain in the “experimenting or “learning stage” for many years. During this stage the practice change is rarely taken to scale over a farm or ranch. Thus, the traditional definition of early adopter perversely assumes immediate proficiency and assumes that the financial costs to become a true “adopter of a technology early” are a one-time cost. We reject this definition because any investment in a practice change isn’t solely about money. It’s also about building confidence enough to trust the wellbeing of your family’s economic health. And, because the new goal of reducing GHG’s and improving soil carbon is not the “Crop” any early adopter farmer ever focused on “growing”. The shift in knowledge, equipment, new practices, and reading the tea leaves requires long time periods to final settle into a resilient new farming/ranching practice adaptation.   
  
To determine that the greenhouse gas (GHG) removals from the mitigation activity would not have occurred in the absence of the incentive created by carbon credit revenues, we implemented the Financial Additionality Test as defined below.

**If the answer is that your activity change would not have occurred at a meaningful economic scale without the addition of new revenues, such as from carbon credit sales, then your project has passed this test of additionality.**

**Evaluate your project using the Financial Additionality Test**   
This test asks the two questions below.You can elect to answer these financial test questions for the first year of operations after changing your practices, or if your business plan is a multi-year program plan, you can choose to base your answers on your predicted multi-year plan and “break even analysis”. We also allow you to answer the questions based on your understanding at the time of your application. But we give you the flexibility to report when a credit is to be generated so that the reality of the financial performance for the startup conversion year(s) to the new practice is real and truly understood. Rainfall, materials and commodity costs/pricing changes so rapidly that any practice change usually involves a few years of experience, and thus the questions may only be accurately answered only a few years after you change a practice.

**Question 1: Was the carbon credit revenue re-invested into the farming/ranching operations, management, and/or infrastructure, and labor needed to operate the facility.** Infrastructure is defined as improvements in paddocks, fences, fencers, batt-latch gates, herd size, water systems, planting or diversification of pasture forage base including brush reduction; improvements in forage base, including noxious weed control, etc. Management and operations are defined as the labor and technology (record keeping, planning technology, communications technology, etc.) required to ensure success.

If the answer is **YES**, then you pass the financial additionality test. If the answer is **NO**, then you must answer Question 2.

**Question 2:** **Did you experience less revenue being available for you to adopt the activity change than your ranch or farm plan suggested was going to be generated?** If the answer is **YES,** then you pass the financial additionality test. If the answer is **NO** to both Questions 1 and 2, then you do not pass the financial additionality test.

**Proof of Meeting the Financial Additionality Test:**   
Applicants must provide a third party financial attestation document that the farmer, rancher, landowner, or their management staff have provided information to answer Question 1 or Question 2 affirmatively. This information may be based on the past or current year’s activity or a multi-year plan as described above.

**Financial additionality attestation**-A required written attestation provided by the landowner/operator to the project proponent, included in the PDD that is then verified by the independent verifier for the listed, registered property/project is required. This attestation must affirm that the majority of carbon revenues were needed/used on the property/project to implement the activity changes, and supporting needs of staffing, labor, infrastructure, (etc) in the PDD. Said attestation is to be presented as a formal attachment to the PDD by the project developer.

This attestation is sufficient proof. However, if the project proponent chooses, the following are examples of additional information, if referenced in the attestation document, can serve as attachments to an attestation:

* A farm or ranch plan or multi-year plan showing past or planned costs and investments.
* Increases in labor required or technology costs (record-keeping, communications, etc.), or other increased management and operations needs to carry out the project activities and ensure success.
* Additional infrastructure, physical improvements or equipment (such as adding or improving paddocks, fences, fencers, batt-latch gates, herd water systems, planting or diversification of pasture forage base, improvements in forage base, including noxious weed control) that are connected with the project activities.
* Any other form of documentation that the carbon credit revenue was a substantial contributor to the ability to make practice changes and carry out the project activity or to accelerate the practice changes and project activity.
* Any other form of documentation that the carbon credit revenue contributed in a significant way to the financial stability, viability, and fiscal confidence of the farm or ranch so that the project activity can continue.
* A signed letter from a banker, accountant, or other financial agent or fiduciary who attests that the revenue from the carbon credit generation is necessary for the sustainability of the project activity.

1. **Performance Standard Test  
   Objective**:   
   To determine that the greenhouse gas (GHG) emission reductions or removals from the mitigation activity are resulting from the implementation of additional practices, or changes in practices, that are resulting from activities considered common practice or enhancing common practice. For example, while annual mold-board plowing tillage is not allowed as a common practice, conversion to no-till with occasional mold-board plowing is a common practice during wet years, that is allowed under this method. Continuous grazing is not allowed, while in some settings livestock may be used for invasive plant management as continuous grazing would be a common practice for a limited time to bring an invasive plant species under control.

**Evidence to be provided:**  
  
**Question 1**  
List the key practice changes to be implemented, and document that the practice change is a common practice and NOT listed on the negative practice lists (maintained by TRS), for specific parts of the

country. If the practice change is on a common practice list, then the performance standard test is passed by your project. If the practice change IS on the negative lists, you must answer Question 2.

**Question 2**Can the project proponents show project-specific factors to demonstrate that the part(s) of a project on the negative lists should actually be considered additional? Considerations can include specific unique characteristics of this land that render the common practices less relevant. Considerations can also include ongoing incremental adoption of more advanced regenerative practices above and beyond the common practice. The applicant must document this with verifier confirmation to demonstrate that greenhouse gas (GHG) emission reductions or removals from the mitigation activity are resulting from the implementation of additional practices, or changes in practices, and are not resulting from common practice. If the answer is YES, then the performance standard test is passed by your project. If the answer is **NO** to both Questions 1 and 2, then you do not pass the Performance Standard Test.

1. **Measured Additionality Test  
   Objective:**   
   The quantitative greenhouse gas (GHG) removals resulting from the mitigation activity must be determined on the basis of rigorous, science-based, field sampling and analysis.

**Evidence to be provided:**The most relevant additionality test is the rigorous field sampling of improvements in soil organic carbon. If the improvement doesn’t occur, then under The Regenerative Standard there is no carbon crediting and no revenue generated. If there is an improvement between predicted and future measured carbon (for interim crediting) and between the baseline and time-one remeasurement (measure to measure improvements) then carbon credits can be generated and made available for sale.

The balance of The Regenerative Standard documents the standard procedures that must be used to do field soil sampling, laboratory measurements of soil carbon levels, and also the computational procedures to document changes in soil carbon stocks. If there are positive changes these are called accruals and this outcome can generate credits meeting the Measured Additionality Test.

**If additional soil organic carbon stocks are measured in your soil from the repeated sampling soil tests and if projections predict improvements for interim releases of credits during years when actual measurements are not conducted, then, YES, you have passed the Measured Additionality Test.**

### 

**The TRS Permanence measures:**

**Permanence**Permanence is a reasonable and adequate assurance that the atmospheric carbon removal created by a project is secured and guaranteed for at least 40 years and that reasonable and adequate measures are implemented and secured for this time to monitor and observe any carbon removal reversals. The buffer pool is designed to compensate for carbon removal reversals, regardless of the reason of those reversals.  
  
The biophysical permanence of soil organic carbon is summarized as a preface to TRS requirements for how permanence is monitored, how reversal risk is tested, and how reversals are mitigated:  
  
1. Soil Carbon Durability and main reversal risks  
2. TRS Soil Carbon permanence monitoring  
3. TRS Soil Carbon reversal risk mitigation measures

**1. Soil Carbon Durability and main reversal risks**

**Background**

The Regenerative Standard addresses permanence and additionality, including the option for project developers to use a static baseline in ways that are consistent with the leading science. The Regenerative Standard differs from other standards by mandating actual soil organic carbon measurements, to document and characterize carbon (and ecosystem) dynamics: decline, reversals and changes from what a healthy ecosystem would provide, and to derisk or reverse that trend through a change in management. The Regenerative Standard recognizes and integrates the tendency and trajectory of healthy ecosystems to become “***stingy”***—meaning they hold nutrients, soil carbon, water and biodiversity, while degraded ecosystems do the opposite: release nutrients, often erode excessive amounts of soil, and allow high levels of stormwater runoff. When disturbance regimes occur in a healthy ecosystem (one which has a long adaptive evolution history), ecosystem functions demonstrate a high level of resilience at the landscape scale.

**Background (continued)**

Pre-perturbation (e.g. wildfire, bioturbation, flooding, etc.) functional measurements suggest a recovery timeline of 2-5 years for otherwise healthy ecosystems (Apfelbaum and Haney 2010, 2012). This process of recovery of “stinginess” happens even in the most dynamic systems where diverse and productive functions re-assemble to maintain the core ecosystem dynamics. The Regenerative Standard recognizes this innate tendency, even in highly disturbed lands, and also recognizes that the exact form of the ecosystem may change but the patterns of function collapse back to “stinginess” manifest, supported by an aligned management system.

Although agricultural soil carbon sequestration is sometimes classified as “temporary” or “low permanence”, this is not aligned with the scientific understanding of the actual durability of soil carbon. Soil Organic Carbon [SOC] stocks are one of the most stable and durable and abundant forms of organic carbon in nature. On our planet, there is more organic carbon in the first 1m (39.4 inches) of soil than all biomass and atmospheric carbon combined. The soil has been one of Nature’s primary places (after the Oceans) to store organic (and inorganic) carbon. Nature has been storing carbon in soil for hundreds of millions of years.  
  
The scientific community understands the durability of soil organic carbon stocks**.** Scientific understanding of the durability of soil carbon, especially that of mineral associated fractions, suggests a durability for thousands to tens of thousands to millions of years or more (Cotrufo and Lavalee 2022, and Lavallee, Soong and Cotrufo 2019, Mosier et al 2021). Some projects have documented soil organic and organic carbon stocks that have been measured in the millions of years of age. The documented durability and longevity are many multiples longer than the age of carbon stocks as customarily measured in trees, and even the age of peat substrates on earth which typically range from 10,000 to 100,000 years of age (United Nations Environmental Program Global Peatlands Assessment 2022).  
  
Individual carbon containing molecules in soil are highly dynamic in a living and thriving soil ecosystem. The carbon of an atmospheric CO2 molecule captured today might be released back into the atmosphere via a chain of highly complex biochemical and biological processes in a matter of a few hours. This does not imply low carbon durability. While individual carbon containing molecules in soil might not be permanent, or durable, as viewed through various mindsets (regulatory construct or an engineering mindset) which perceives carbon as if it were stored in a closed vessel, the true ecological analysis shows that bulk soil carbon stock is very stable and durable and continues to accrue in a dynamic equilibrium with plant productivity, microbial productivity, and bio-geochemical cycles driven by moisture and photosynthesis.

**Evaluating Reversal Risks and Buffer Pool Options**

The same framework is to be used for evaluating and development of the buffer pool for shortfalls and reversals during the crediting life of any project and also for the Post-crediting Period (See Glossary of terms). Appendix 9.0 provides a framework for evaluation and election by the project developer for ensuring funds for the post-crediting monitoring period buffer.

The Regenerative Standard and Nature’s Registry have evaluated and documented the multiple ways different soil carbon protocols address permanence and how they mitigate for reversals.[[2]](#footnote-4) The Regenerative Standard has developed a comprehensive and pragmatic risk-based permanence framework that evaluates the primary natural and direct human caused reversals to assess permanence (Please see **Figure 1**) as an encouraged option for users of TRS. However, we also recognize several other options used for this same purpose that may be selected by project developers as follows:

**Buffer Pool Assurance Options:**

TRS is focused on the use of the risk-based buffer pool described below. However, applicants may choose from several different options:

### Option 1: Set Permanence

**Retainage**No less than 10% of the credits issued from the project will be withheld in a buffer account.

**Option 2. Risk-based Permanence Retainage**

This is TRS’s encouraged and preferred Buffer Pool and reversal risk tool.

**Option 3. Statistical Variance Method to Inform Retainage**

If variances in estimating the mean carbon stocks across properties is equal to or less than 10%, the statistical results can be used as a basis for estimating and determining the buffer retainage from a project.

**Option1: Set Permanence Retainage**TRS requires the project developers to deliver at least 10% of the credits generated to the buffer pool. The Registry will manage the buffer pool.   
  
The Registry has the mandate to increase this buffer to levels higher than 10%, based on general risk assessments for the portfolio of projects, or a specific risks assessment for specific projects. If the Registry determines to increase the buffer above 10%, the registry must document the science-based rationale that an increase above 10% is a reasonable requirement to safeguard the permanence guarantees for the credits. The Registry has the mandate to reduce permanence levels from higher than 10% back to 10%.   
  
 **Option 2. Risk-Based Permanence Retainage**

This is TRS’s encouraged and preferred option, and it requires project developers to apply a pragmatic permanence framework that uses the primary documented risks to the permanence of soil organic carbon [SOC] stocks. This includes six key natural risks, and an additional seven key direct human caused risks, also called avoidable risks. These risks to impact permanence are further divided into impact on shallow (top) soil (<30 cm) and impact on deeper soil layers (30-100 cm). Using this option, no less than 8% of the credits issued from the project will be withheld in a buffer account, and the exact percentage is calculated based on these combined risks.  
  
The scientific literature provides examples of the approximate magnitude of each risk, for SOC decline and the depth of loss in the soil system. Most risks are primarily shallow in nature (<30 cm depth) and affect what is well documented to be present in these shallower depth strata as short-lived particulate carbon fractions. Only a few risks from stochastic events and chronic direct human induced changes (avoidable impacts) affect deeper soil depths (> 30 cm) which typically contain the long lived, mineral associated carbon fractions. These are fractions that are well documented to achieve thousands to hundreds of thousands of years of durability or older age. And these deeper soils are the locations where soil organic carbon conversions to even more stable mineralized carbon, and leaches soil inorganic carbon fractions (which also reside in most soil systems), which can be millions of years in age and durability.

The key nature induced risks to SOC durability are:

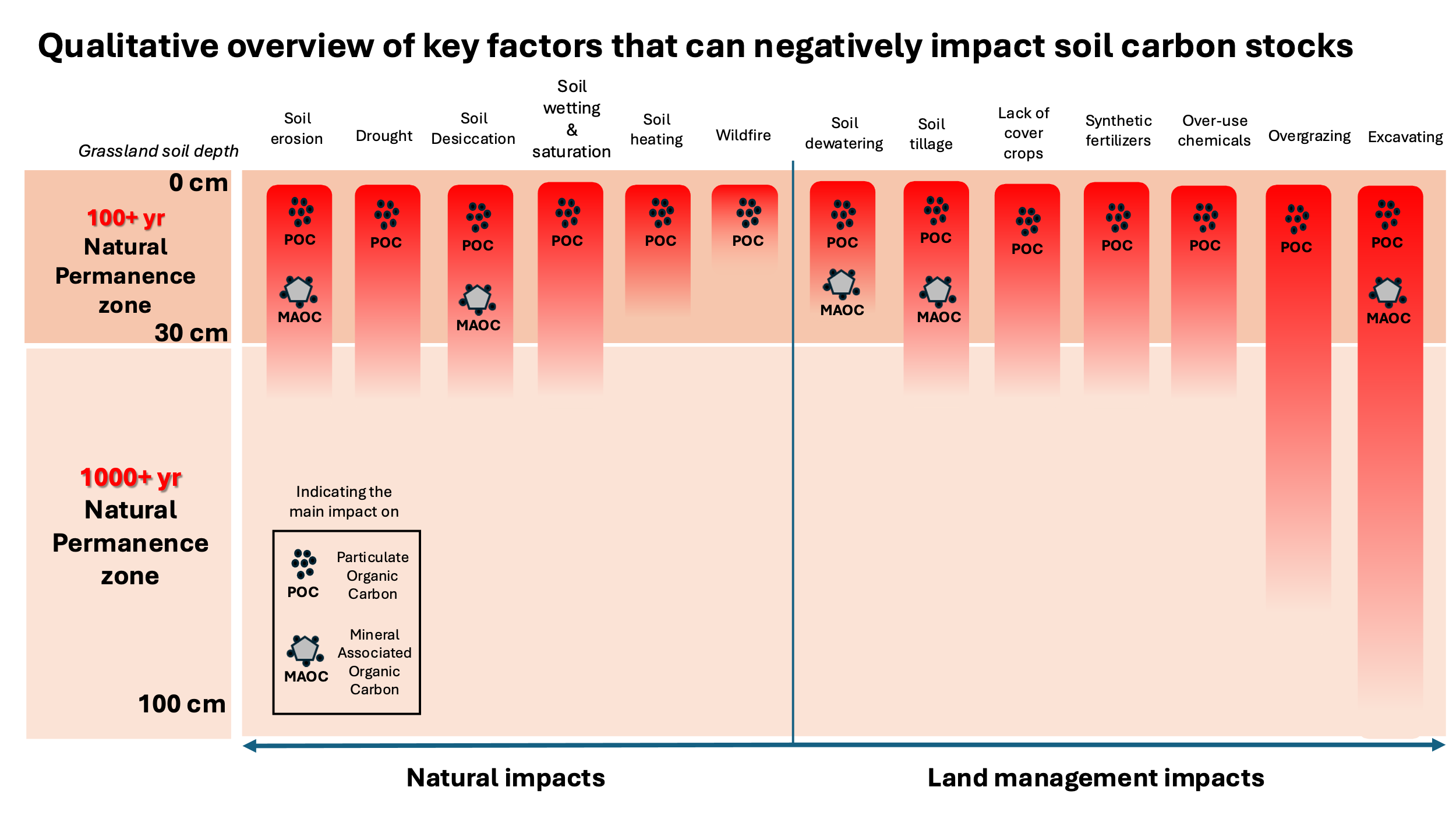
* wildfires
* soil heating
* soil wetting and saturation
* soil desiccation
* drought
* soil erosion (often the result from the previous risks, or human induced risks)

The key human induced, or avoidable risks to SOC durability are:

* soil dewatering
* soil tillage
* lack of soil cover by vegetation
* synthetic fertilizers
* over-use of chemicals
* drought
* overgrazing
* excavating

Generally, it can be stated that natural impacts on SOC stocks mainly impact the shallower soil layer [<30 cm], while human induced risks, or avoidable risk chronically impact shallower (e.g. think about the annual tillage of a farm field) and stochastic events affect deeper SOC stocks (e.g. think about deep gulley erosion events after the dust bowl in North America in the 1930’s). Healthy ecologies and their soil systems are more resilient to most of the key risks that can reduce SOC. **Figure 1** provides an indicative summary overview of the 13 key risks and qualitative key impacts on SOC stocks for a shallow soil layer (<30 cm) and a deeper soil layer (>30 cm).

Project developers are required to include in their PDD an excel spreadsheet with the risk assumptions for each of the natural and human-induced land management impacts as the basis for demonstrating a reasonable assessment of risks on each property/project submitted for crediting.

  
  
**Figure 1 - An indicative overview of 13 key risks and a simplified qualitative summary of the key impacts on SOC stocks for a shallow (<30 cm) and a deeper soil layer (>30 cm).**

If a project developer decides to apply for Option 2 [Risk Based Permanence Retainage], the project developer must demonstrate, on basis of transparent reasonable scientific based data and assumptions, for a specific project what the risk-based permanence buffer pool contribution percentage should be. The Risk Based Permanence Retainage, proposed by the project developer, must be accepted by the third party verifier and the science officer for the Registry.  
  
The project developer must demonstrate and document (on basis of transparent reasonable scientific based data and assumptions) for each of the six key natural risks, and the additional seven key direct human caused risks, also called avoidable risks, what the likelihood of occurrence is in the permanence period and what the SOC impact can be for each of these risks, with in addition, a reasonable safety factor. Please see the Applied Ecological Institute web site for the summary of a literature review evaluation of the primary risks (<https://www.aeinstitute.org/resources-1>). This is intended to help in a project developer assessment of permanence risks. A Permanence-risk worksheet is provided below as guidance to help applicants arrive at a reasonable safety factor:

**Permanence-Risk Worksheet**

For each potential risk to the permanence of soil organic carbon sequestered during your project, estimate the percentage of the land impacted over the last decade that may have contributed to baseline (time-zero) soil carbon measurements and use this understanding to the potential estimated risks during the crediting and monitoring period for your project.

For each risk assess the following questions:

* + - 1. Will this risk occur on the project site? Enter a **“0”** if your answer is NO. Enter a “1%” and go to question #2 if your answer is “Yes”.
      2. Will the risk be episodic or chronic? Enter a “1.0 for both”. Continue to Q. 3.
      3. Will the risk affect only <30cm, 30-100 cm, or the entire soil profile? If <30 add “0.75%”. If 30-100cm add 0.25%. If the entire soil profile is impacted add “1%”. Continue to Q 4.
      4. Will the risk be very localized impacting < 1% of the land, dispersed but small in scale, or broadly affecting carbon stocks? If the risk affects < 1% of land add 0.1%. If the risk isdispersed/small scale add 0.2%. And if the risk broadly affects carbon stocks add 0.7%).
      5. Is there the risk a catastrophic, widespread loss of SOC from a combination of permanence risk factors, For NO, add a “0”. For Yes, add a “1”.

**Example Use-Case – Soil carbon change under buffalo grazing regiment**

In the example we assess a 30,000 acre native (C4) warm season grassland used for buffalo grazing in South Dakota. Measurements of percent plant coverage averaged > 90% in all but several areas excluded from crediting, which included a badland geological formation settings, prairie dog colonies that occupied several hundred acres, a bedrock expanse, and a sacrificial paddock where bison were annually confined for a week while they were being treated for required inoculations, and lastly the buildings, roads and developed acres were also excluded. Bare soil measurements over the included acreage averaged < 1%. Scattered very small scale (< 500 square feet each) dry wallows were used by buffalo for dusting were observed to be present for decades. Stream channels, beds and banks, and dry washes were all heavily vegetation with dense native willows, sedges, and native grasses and forbs.

We studied the site during the last year of what was a 7-year drought, and again eight years after the drought ended. There was no significant difference is shallow or deep SOC stocks in the comparison of baseline (Time-zero) and Time-one sampling periods in coarse textured sandy loam soils. However, finer silt loam soils were documented to experience numerical increases in SOC, some being statistically significant **(Mimi Hillenbrand, et al., Agriculture, Ecosystems and Environment, https://doi.org/10.1016/j.agee.2019.02.005).** Here, we demonstrate the use of. Permanence risk worksheet to develop a risk calculation:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Impact on SOC permanence** | **Maximum score** | **Q 1** | **Q 2** | **Q 3** | **Q 4** | **Q5** | **Sum** |
| **Natural Event caused** |  |  |  |  |  |  |  |
| Soil erosion | 5 | 1 | 1 | 1 | .2 | 0 | 3.2 |
| Drought | 5 | 1 | 1 | .75 | .2 | 0 | 2.95 |
| Soil Dessication | 5 | 1 | 1 | .75 | .1(South/West side slopes only) | 0 | 2.85 |
| Soil wetting/inundation | 5 | 0 NA |  |  |  | 0 | 0 |
| Soil Heating | 5 | 1 | 1 | .75 | .2 (South/West side slopes only) | 0 | 2.95 |
| Wildfire | 5 | 0 NA |  |  |  | 0 | 0 |
| **Human Induced/caused** |  |  |  |  |  |  |  |
| Soil Dewatering | 5 | 0 NA |  |  |  | 0 | 0 |
| Soil Tillage | 5 | 0 NA |  |  |  | 0 | 0 |
| Lack of Cover Crops/Bare soil | 5 | 0 NA |  |  |  | 0 | 0 |
| Synthetic fertilizer | 5 | 0 NA |  |  |  | 0 | 0 |
| Chemical over-use | 5 | 0 NA |  |  |  | 0 | 0 |
| Overgrazing | 5 | 0 NA |  |  |  | 0 | 0 |
| Excavation/Compaction | 5 | 0 NA |  |  |  | 0 | 0 |
| **SUM** | **65** |  |  |  |  |  | **11.95** |
| **AVERAGE** | **5** |  |  |  |  |  | **.919** |
| **STANDARD DEVIATION** | **0** |  |  |  |  |  | **1.4** |

The conclusion of this assessment suggests the permanence risk from natural human induced causes is de minimus as evidenced by the durability of the retained carbon stocks through the drought, heating, desiccation years and the improved SOC levels after drought in fine textured soils. The retained native plant species composition, comparable standing crop biomass and low % bare soils between sampling events confirms a minimal impact, if any, experienced on this ranch. The average SOC permanence risk score of 0.919 compared to the maximum SOC permanence risk score of 65 suggests a very low risk to permanence would be predicted, of perhaps 1.4% risk. This percentage would be a reasonable buffer retainage to consider for a ranch with this performance and low risk.

**Option 3. Statistical Variance Method to Inform Retainage**

If variances in estimating the mean carbon stocks across properties is equal to or less than 10%, the statistical results can be used as a basis for estimating and determining the buffer retainage from a project.  
  
If a project developer decides to apply for Option 3 [Statistical Variance Method to Inform Retainage], the project developer must demonstrate, on basis of transparent reasonable scientific data and assumptions, for a specific project what the risk-based permanence buffer pool contribution percentage should be. The Risk Based Permanence Retainage, proposed by the project developer, must be accepted by the third party verifier and science officer of the Registry. As an example of how this process works, using 1 m length soil core sample results, and assuming the following are the Total SOC from fifteen core samples from one sampled landscape strata: **Frequency Distribution**

**Sample # Tonnes SOC/acre TSOC/acre # of Samples**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample 1 | 110 |  |  |  | <80 | 1 |
| Sample 2 | 114 |  |  |  | 80-100 | 1 |
| Sample 3 | 112 |  |  |  | 110-120 | 10 |
| Sample 4 | 111 |  |  |  | 120-140 | 2 |
| Sample 5 | 79 |  |  |  | >140 | 1 |
| Sample 6 | 114 |  |  |  |
| Sample 7 | 358 |  |  |  |
| Sample 8 | 105 |  |  |  |
| Sample 9 | 114 |  |  |  |
| Sample 10 | 120 |  |  |  |
| Sample 11 | 101.5 |  |  |  |
| Sample 12 | 113.7 |  |  |  |
| Sample 13 | 115 |  |  |  |
| Sample 14 | 125 |  |  |  |
| Sample 15 | 97.5 |  |  |  |
|  |  |  |  |  |
|  | With Outlier | Without Outlier |  |  |
| Mean | 126.0 | 109.4 |  |  |
| STD | 65.1 | 11.2 |  |  |

After running statistical tests (to confirm normally distributed data (if parametric statistics will be used), the variance and an outlier test suggest the following is learned:

* From the frequency distribution the data are normally distributed.
* **Sample 7=358.0** is a statistical outlier (That a user can formally affirm with SYSTAT, PCORD, JP, SPSS, “R”, or other standard statistical analytical software package). If the outlier can be explained, it can be eliminated from this data set. This outlier sampling point occurred on a soil type boundary that was found to be field mapped inaccurately;; As a result Sample 7 is excluded from this data set and has been included in the appropriate adjacent soil type and ecological strata for further analysis.
* Mean with outlier in the data set is = **126.1** TSOC/acre with a Standard Deviation of **65.1**.
* Mean with outlier removed is = **109.4** TSOC/acre with a Standard Deviation of **11.2**.

Using this analysis, the Standard Deviation of 11.2 could be considered by the proponent as the buffer pool retained percentage of credit, not available for sale, under this option.

1. **NOTE:** Following the TRS methods for soil carbon project sample planning, landscape biophysical stratification, sampling, lab processing including chopping core samples at least into four segments—“A” horizon, subtended by three depth strata (starting below the “A” horizon) reduces a 20-30% error in carbon sampling by mixing “A” and “B” soil horizon soils to varying and unreproducible (especially in landscapes with highly dynamic surface soil setting) admixtures over time when only depth increment sampling is used (See Apfelbaum et al. J Envi Soi Sci 6(3) - 2022. OAJESS.MS.ID.000239. DOI: 10.32474/OAJESS.2022.06.000239; and Kimbal et al 2007, CRC Soil carbon management, economic, environmental, and societal benefits).

**2. TRS Soil Carbon permanence monitoring**

To provide a reasonable and adequate assurance that the atmospheric carbon removal created by a project is secured and guaranteed for at least 40 years, preferably 100 years, TRS requires the project developer to implement, maintain and guarantee the deployment of measures to timely monitor and document any carbon removal reversals.

**Roles and Responsibilities: TRS Soil Carbon permanence monitoring**

* *The Project developer:*The project developer is responsible and accountable for the implementation, maintenance and quality of the system or set of measures to frequently and timely monitor and observe any carbon removal reversals.
* *Independent third-party verifier:*The independent third-party project verifier must include an assessment of the quality of the system or set of measures to frequently and timely monitor and observe any carbon removal reversals, operated, and maintained by the project developer.
* *The Registry:*The Registry used to register and maintain the ledger of carbon credits generated according to TRS, is responsible and accountable to frequently review if the systems’ set of measures, used by the project developer to frequently monitor and timely document any carbon removal reversals, is adequately useful for this purpose.
* *The Registry - Mitigation plan:*  
  The registry must maintain an active set of standards in the form of a mitigation plan describing in adequate detail what pragmatic actions must be implemented by the project developer/landowner, and affirm the system or set of measures to frequently and timely monitor and observe any carbon removal reversals, in case:
  + The project developer ceases to exist or is incapable or unwilling to execute its monitoring roles and responsibilities.
  + The registry ceases to exist or is incapable or unwilling to execute its monitoring roles and responsibilities.

The carbon reversal monitoring system for each project should comprise a portfolio of at least some of the following tools and mechanisms:

* A contractual agreement between the project developer and landowners in the project to restrict the use of land management practices that form a risk to SOC stocks for the specified permanence period.
* A frequent, for instance annual, formal declaration (affidavit) of the landowner submitted to the project developer, that key land management risks and key natural risks did not occur at the property, or if they did occur to what extent.
* A frequent, for instance once every 5 years, use of adequate remote sensing tools and techniques to observe any of the key risks that might lead to carbon removal reversals.
* A frequent, for instance once every 5-years, visit of the project site to observe any of the key risks that might lead to carbon removal reversals.
* Other adequate methods, tools and techniques that will provide frequent (e.g., yearly) and a timely observation of the occurrence of key risks that might lead to carbon removal reversals.

During the phase in which the project is actively delivering carbon removal credits according to TRS, carbon removal credits are generated frequently (e.g. annually) which requires an assessment of the carbon storage accrual, and a frequent (e.g. every 5-years) measure to measure determination of the SOC. For every credit delivery application, independent third party verification of the lack of occurrence of carbon removal reversals is mandatory.  
  
During the phase in which the project is no longer actively delivering carbon removal credits, but the permanence period has not yet expired, the project developer must report to the registry annually that the carbon reversal monitoring system has been implemented and where/if mitigation was necessary, how that has been, or will be implemented and the ongoing revised monitoring commitments.

In the case that carbon removal reversals are observed by any party, the project developer has the main responsibility to report to the registry a carbon removal reversal report, including: the location of reversals, acreage affected, estimated quantify of the reversals, date of the reversals and likely cause(s) of reversals. In case the project developer is unable or unwilling to report carbon removal reversals, any party can report the reversals, or suspicion of reversals, to the Registry.

**3. TRS Soil Carbon reversal risk mitigation measures**Oncea carbon removal reversal has been observed or reported the next step is to ensure that the carbon removal reversal is adequately and timely compensated and thus effectively eliminated. The following TRS procedures describe the portfolio of actions and measures to guarantee adequate TRS credit permanence.

**TRS Buffer Pool Requirements**

The TRS buffer requires a 40-year minimum commitment to monitor, report, and compensate for reversals. TRS requirement details addressed in this section include:

* Projects are required to contribute to a pooled buffer operated by Nature’s Registry.
* Project credits retained in the buffer pool are not returned to the project developer or landowner at the end of their permanence/storage period. ***Note:*** *This is a change from projects developed under previous versions of The Regenerative Standard.*
* Project credits included in the buffer pool can be used for shortfalls and/or reversals, either avoidable and/or unavoidable.

**Buffer Program Execution and Participation**

TRS has established a buffer pool “insurance program” against avoidable and unavoidable reversals to guarantee permanence and trust that carbon credits always represent actual atmospheric carbon removal, based on measured improvements in soil organic carbon stocks in soil.

* **Retainage/Contributions to Buffer Pool**
  + Each project must at the time of project registration commit to participating in the buffer pool as an eligibility requirement of TRS.
  + The verifier reviews the permanence test applied to the project and the results, and the verification report confirms that the project PDD includes an appropriate level of credit retainage proposed by the applicant that would be moved to the buffer pool upon Nature’s Registry approval, certification, and issuance of credits for the project.
  + The retainage must meet the TRS retainage guidelines to ensure the buffer pool is adequately and appropriately de-risked to address reversals, and any shortfalls of any type over, at least, forty years.

**Retainage Guidance**

The buffer pool creates the assurance that applicant reversals and shortfalls can be timely mitigated so that the sales of carbon removal credit don’t exceed the improvements in soil carbon stocks that can be credited as carbon removal credits from any project over time.

The buffer pool should be viewed as the equivalent of a bank account that is constructed from credits which can be used to compensate for shortfalls or reversals, by the Registry debiting against the buffer pool to provide the compensation.

Whereas the TRS method is predicated on trusted science as measured from repeat soil sampling and SOC analysis on the ground.

Whereas the voluntary carbon market depends on robust and credible market representations of credit yields from each participating project.

Whereas, on the ground activity changes, meteorological changes, and landowner land management decision making may contribute to deviations from projections during interim crediting periods between the baseline and remeasurement periods for soil organic carbon stocks to determine crediting achieved.

Therefore, the following rules must be followed by each project participant in this program:

1. Applicants must commit to participating in the buffer pool to be eligible to participate under the TRS program.
2. Verification report results shall be the applicants direct feedback on the adequacy of the buffer credit retainage required from each project to be deposited in the buffer pool.
3. Buffer pool retained credits shall be deposited as a requirement for credit certification and issuance to the registry.
4. The registry retains the decision-making authority over the entire buffer pool, based on reversal records, to increase or decrease the buffer pool contribution required by each project.
5. The project developer can use the permanence test of risk to estimate and document for the verification process, their proposed project’s contribution to the buffer pool, as described in section 2: option 2 or 3.

Option 2. Risk-based Permanence Retainage  
Option 3. Statistical Variance Method to Inform Retainage

**Buffer Account Governance**

* + *The Registry’s buffer pool account(s) represents an insurance program for each participating project to ensure no oversales occur in the marketplace and each credit sold in the marketplace represents atmospheric carbon removal for the permanence period of at least 40 years.*
  + *The Registry establishes, maintains, manages, accounts, and makes available for internal and external audits the buffer pool account performance and records.*
  + *Shortfall compensation records and reports are generated by the registry quarterly and used by the registry to make any adjustments in the required retainage from future projects, or future annual tranches of credit generated for sale from the same project over time.*
  + *The Registry holds as a part of the ledger records on each project’s contribution to the buffer pool.*
  + *The Registry quarterly documents shortfalls or reversals from each project in the ledger. A ledger report is available to each project developer and landowner via the on-line project portal and through automated direct emailing to ensure all parties understand the status of accounts, shortfalls, reversals, and credit status.*
  + *If a project is experiencing shortfalls, subsequent tranches from the same project and/or other projects by the same project developer can be used by the project developer to provide annual true-up adjustments in credit retained in the buffer pool.*
  + *The Registry retains the authority and right over time to adjust buffer credits in the buffer pool should representations made by the project proponent result in an overstatement of the number of actual measurement-based credits deposited in the buffer pool.*
  + *The Registry can only liquidate (trade/sell) a commensurate quantity of credits from the buffer pool should some extenuating circumstances such as market adjustments, or policy changes result in a diminishment of the number of credits generated, number of credits in the buffer pool, or other unpredictable circumstance.*

**Addressing Reversals**

* ***Avoidable reversals*** *– Human induced impacts on SOC stock permanence are to be compensated by the project developer and landowner. If the project developer and landowner fail to timely compensate, the buffer pool will be used.*
* For avoidable reversals, after written notice, the landowner is the first party responsible, during a two growing season period, to generate other shortfall compensating credits or purchase equivalent credits to compensate for the avoidable reversal. After this two year period, failure to compensate would invoke the Registry to debit the buffer pool account of the project and then necessitate that the buffer pool account be replenished by the project proponent. In this situation the buffer pool is used as a buffer to provide timely compensation of shortfalls, before the landowner and project developer are replenishing the buffer account.  
  ***Unavoidable Reversals****- Nature induced impacts on SOC stock permanence will be compensated by sharing, as explained below, with the developer, landowner from the buffer pool with the following requirements:*
* After written notice, the project applicant and landowner shall have two years to provide and deploy an affirmative compensation plan meeting a verification and Registry review to result in satisfying the reversal. During this period of time, the project developer must document the cause of the reversal and how the compensation plan avoids the causative agents contributing to the unavoidable reversal from recurring. Only after verifier confirmation and concurrence by other objective third party reviews and Nature’s Registry will Nature’s Registry consider debiting the buffer pool to help compensate at some level for unavoidable reversals. In this situation the buffer pool is only used as a buffer to provide timely compensation of shortfalls, but the landowner and project developer are required to replenish the buffer account for the amount of credit debited by the Registry to address any shortfall.
* For unavoidable reversals, the project proponent shall always be fully responsible for compensating the buffer pool should the registry provide shortfall debiting the buffer pool. And this will only occur if the project developer has a functioning compensation plan in place to generate the required credit quantity and quality. A second written notice is given to the project applicant and landowner to formalize the intent and agreement to debit the buffer pool. At such a time. Nature’s Registry will place a hold on a quantity of remaining credits in the project developers account(s) that cannot be traded and will be retained as collateral until the buffer pool is formally replenished by the project developer.

***Process and Timing on addressing reversals and shortfalls***

* + *Indications and/or evidence of a reversal shall trigger the requirement of a project developer/landowner to investigate and report to explain the reversal and estimate the losses.*
  + *Evidence of shortfall shall trigger the same requirement for a developer/landowner report to explain the shortfall estimate.*
    - *The evidentiary project plan shall be created by the project developer/landowner to compensate for the reversal/shortfall with adequate details, and this plan should be submitted to the previous verifier of record, to the Registry, and retained to submit during a future verification the next time the project seeks to generate credits.*
    - *The Registry can decisively issue a reversal acceptance order, an order of inconclusive or uncertain findings, or an order rejecting the plan for reversal.*
    - *The Project developer and landowner will have 90 days to accept or modify findings to revise the reversal mitigation remedy plan.*
    - *The Project developer and landowner will have two growing seasons after acceptance of the plan to create the compensation, or can agree at the time of submitting the reversal mitigation remedy plan to accept the following compensation requirement.*
    - *At the project’s next verification event, such as the next time it seeks to generate credits, the verifier should review and verify any reversals that were not previously verified.*

***Mitigation Procedures for project developer/landowner***

* *Buffer compensation can involve cancelling credits held in the buffer pool so that other credits for sale will still be valid for trade/sale.*
* *A compensation plan must focus on mitigating with valid measurement-based (not projections and modeling) credits that exist or that can be demonstrated through repeated sampling have a 90% probability based on past performance to exist within the two year time window of any plan to accomplish the reconciliation.*
* *A compensation plan can involve a new deposit of certified issued measurement-based unsold credits.*
* *Additional instruments of surety can be used by the project applicant in the compensation plan. These may include insurance instruments that allow the project developer, landowner, or Registry to purchase compensation from other credit sellers with bonified measurement-based credits.*
  + *Pooled Buffer cannot be used for a project to cover verifier reviewed and verification report confirmed project-specific shortfalls.* 
    - *The project plan for a shortfall shall identify how a project developer/landowner plans to address the shortfall.* 
      * *Strategy #1 is that any new credits that a project may generate over the following two years shall be the primary source of new credits to cover project shortfalls.*
      * *Only after a period of two years if the project is unable to generate credits to cover the shortfalls then the Registry may choose to use the Buffer pool to cover those shortfalls.*
      * *If the buffer pool is debited to cover a shortfall, the project developer/landowner must replenish the buffer pool using its future years of credits generated before it can resume generating credits that can be sold.*
    - *In the event the compensation plan is still not acceptable or not believed to be achievable by the verifier or Registry, the Registry will debit the next tranche, any remaining unsold credits for as much as 100% of the reversal credit mitigation needs prior to debiting from the buffer pool.*
* Monitoring and Reporting
  + *Annual reporting must be detailed in each reversal/shortfall compensation plan.*
  + *If a project lapses in monitoring or reporting, during and/or after the crediting period or storage/permanence period, a formal notification shall be given by the Registry to the project developer/landowner.*
  + *If the compensation or mitigation for reversals/shortfalls is not adequately made and if monitoring and reporting lapse continues, the Registry will provide written notice to cease and desist in credit sales. The applicant, project developer, and landowner will respond within 30 days with the required monitoring and Reporting. If said report is not received by the registry, the applicant/project developer and landowner will all be notified their project is a delinquent project and is no longer in good standing for selling or trading carbon credits.*
  + *The applicant/developer/landowner will have another 30 days to resolve the delinquency.*
  + *If the delinquency is not resolved, either by submittal of a refined, revised mitigation plan, or submittal to the verifier with an accepted updated verification report approving said plan, then the delinquent project shall be put on suspension, formally with a suspension notification delivered by the Registry to the applicant/project developer and landowner.*
  + *Suspension notification will mean remaining unsold carbon credits that were issued by the Registry will have their certifications removed, until further notice.*

### Credit Release

Credit releases following an annual verification is the expected standard of this methodology. Credit releases can occur annually, or at the timeline scheduled in the PDD, commensurate with sampling, annual activity reporting, and permanence assurances being in place and only after annual verification occurs. The Project Proponent may select a credit release after each sampling event (e.g. after T0) or, if completing the optional [*Task 3. Interim Crediting Assessment*](#bookmark=id.5cie6kuirofq), an annual release based on verified carbon stock estimates and adjusted by the T1 or subsequent-year measurement under Verra’s [VMD0021 *Estimation of Stocks in the Soil Carbon Pool, v1.0*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf)requirements. Annual releases will be certified with the submittal of the Verification Checklist, as detailed in [*Task 5. Verification*](#bookmark=id.53zkfg5hjmur), verifying that the assumptions in the original application continue as represented. It is critical that credit releases occur in a timely manner to ensure cash flow to landowners and Land Stewards, and availability of registry credits to carbon credit purchasers. See [*Task 6. Registration*](#bookmark=id.1xirrtyhpwe) for more details.

### Contractual Commitment

A Project Proponent must describe the contractual commitment with the Land Steward and/or landowner and enforceable provisions within the contract to address topics such as non-disturbance and permanence terms, land ownership changes, double accounting prevention mechanisms, and how the Project Proponent intends to monitor contractual commitments. A Project Proponent should provide the executed contract with the landowner as proof of meeting contractual eligibility.

## Measurement and Reporting

A Project Proponent must describe the stratification and sample allocation, methods for quantifying soil carbon pools and GHG emissions for the baseline and project scenarios including laboratory and statistical analysis, and reporting. Detailed methods are provided in this protocol through links; below we provide a brief summary for general guidance:



TRS SOC is focused on carbon removal credits to be generated associated with increases in soil carbon stocks, provided those stocks are rigorously quantified using the procedures described above. No credit is currently awarded with TRS SOC V2.0 for *avoided emissions* (See glossary of terms) of GHGs associated with land protection. Crediting is an option to be considered by the project proponent for *reduced emissions* (see glossary of terms) for reduced agricultural inputs such as fertilizers and pesticides, tillage, reduced usage of powered farm equipment. Currently, no crediting is accepted under TRS SOC V2.0 for reduced emissions from livestock or manure operations. This makes TRS SOC V2.0 inherently conservative in terms of the number of credits issued.

However, TRS SOC requires a monitoring plan for leakage that offers a reasonable and sufficient assurance that the net storage of atmospheric carbon in the soil carbon pool has not been negatively impacted by increases in GHG emissions within the project area or elsewhere outside the project area resulting from the implementation of a proposed project.

Changes in carbon pools and GHG emissions related to both project activities and leakage for the project scenario shall be addressed with a two-step process:

1. A qualitative evaluation to determine if the Project Proponent can establish with reasonable and sufficient assurance that the carbon pools and GHG emissions are likely to remain unchanged during the project period (i.e., they are not expected to change by 10% on a time-weighted basis) or the potential changes are transient in nature.
2. If the changes in carbon pools and GHG emissions are not likely to be significant (i.e. less than 10% change expected) and can for all practical purposes be considered *de minimis*, a Project Proponent does not need to quantify these pools and emissions and their value may be accounted as zero for the purposes of carbon crediting.

Otherwise, the magnitude of the changes in carbon pools and GHG emissions must be quantified within the uncertainty limits following validated protocols described below, with zero reductions to carbon crediting if any change is determined *de minimis* based on application of the CDM A/R methodological *Tool for testing significance of GHG emissions in A/R CDM project activities*. A few examples of the many resources that may be helpful in this screening include the following examples from Meta-Analyses (Eagle et al 2011, ICF 2013, Kimble et al 2007 and USDA, 2014).

Use the decision support in Table 1, for reasonable and sufficient assurance that carbon pools and GHG emissions are not changing for the project scenario, the Project Proponent is required to determine, at a minimum, the likelihood of the project activities leading to an increase in GHG emissions either within the project area or outside the project area based on consideration of the most important GHG emissions related to operations in agricultural, grazing, and restoration and conservation lands. Table 1 findings will also be used to inform under Section 3.1 the Interim Crediting Assessment for soil carbon changes from a proposed activity change on a project.

**Table 1. Likelihood of project activities leading to an increase in GHG emissions during the project period**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source** | **Likely to increase** | **Likely to stay the same** | **Likely to decrease** | **Don’t know** |
| Number of animals/livestock |  |  |  |  |
| Enteric fermentation |  |  |  |  |
| Manure deposition |  |  |  |  |
| Use of fertilizer |  |  |  |  |
| Use of pesticides |  |  |  |  |
| Use of hydrocarbon fuel for gas and electricity |  |  |  |  |
| Use of hydrocarbon fuel for irrigation |  |  |  |  |
| Export of hay |  |  |  |  |
| Woody biomass (above & belowground) |  |  |  |  |
| Non-woody biomass (above & belowground) |  |  |  |  |
| Import of animal feed |  |  |  |  |
| Export of animals and animal products |  |  |  |  |
| Burning of biomass |  |  |  |  |
| Use of nitrogen-fixing species |  |  |  |  |

For example, if a decline in agricultural production or significant wood harvesting is likely to occur that would change the project baseline scenario by more than 10%, [*Task 2.6.1 Monitoring and estimation of emissions from grazing, fodder and agricultural production displacement*](#bookmark=id.rr6jkl4kugg6) need to be completed since a change in carbon stocks or GHG emissions might have occurred as a result of the project. Similarly, [*Task 2.6.2 Monitoring and estimation of emissions from wood harvest displacement*](#bookmark=id.cknmdenmgyfg) need to be completed only if significant wood harvesting from the project area is likely to occur, etc.

It follows that if the project does not involve a reduction of agricultural production nor a reduction in wood harvesting after the project start date, then leakage related to these factors would be zero and optional tasks related to quantitative accounting of carbon or GHG emissions do not need to be completed.

Conversely, if the magnitude of the changes in carbon pools and GHG emissions as a result of the project activities during the duration of the project are likely to change by more than 10%, optional tasks for estimation of the carbon content of current pools and the projection of carbon pools and emissions must be completed.

### Quantification of Soil Carbon Stocks for Baseline and Project Scenarios

These tasks relate to the quantification of soil carbon stocks and, as the core measurements for TRS SOC, are required for all projects.

#### Stratification for soil carbon sampling

The stratification process involves assembling Project Boundary, soil, hydrologic setting, and vegetation data and selecting representative and adequate locations in the Project Area for the allocation of random soil sampling points. A stratification process and sampling design, including sample point allocation, should in general follow guidance from [*Task 1.6* *Baseline Scenario*](#bookmark=id.8mif3aei7lbq) and Verra’s modules [TRS-1 *Methods to Determine Stratification*](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/) and [VMD0021 *Estimation of Stocks in the Soil Carbon Pool*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf), to quantify the change in soil carbon stocks over time (e.g. as the difference between carbon stocks in T0 and T1) within the project area and to increase measurement precision in a cost-effective manner. This information gathered both quantifies the existing soil carbon pool and enables projections of future conditions per unit area with statistical rigor.

|  |  |
| --- | --- |
| Requirement | Required for all projects. |
| Goal | To divide the project area into one or more strata within which the projected soil carbon pools and soil carbon dynamics are expected to be uniform under the project scenario, given the stratification determined in Task 2.1, and the proposed treatment under the project scenario. |
| Method | Use module [TRS-1 Methods to Determine Stratification](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/), with soil carbon as the relevant variable X. |

#### Sampling and analysis for soil carbon per unit area, per stratum

The goal is to install sufficient sample locations to meet the required statistical rigor, as discussed in [*Task 2.1.3 Uncertainty of soil carbon stocks*](#bookmark=kix.6uiwgiwzw8rr), below. For example, the Project Proponent may use a number of statistical methods to estimate the expected number of samples required, including those in the [*CDM A/R Methodological Tool Calculation of the number of sample plots for measurements within A/R CDM project activities*](https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.0.pdf/history_view) (Version 2.0 or later).

|  |  |
| --- | --- |
| Requirement | Required for all projects. |
| Goal | To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to estimate at the required levels of statistical precision and accuracy, the amount of soil carbon per unit area. |
| Method | Use module [VMD0021 Estimation of Stocks in the Soil Carbon Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf). |

#### Uncertainty of soil carbon stocks

Projects that utilize emerging technologies ( e.g. satellite data, proximal sensing, chrono sequences, eddy covariance data, shallow core sampling (for example, 30-cm depth) and/or digital soil mapping) for interim crediting or to augment direct soil sampling to 1-meter depth (or to refusal), must demonstrate that the additional methods of measurement predict SOC with sufficient accuracy to meet or exceed the requirements defined in Verra’s [VM0042 *Methodology for Improved Agricultural Land Management, v2.0*](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf)*,* Section 8.6 *Uncertainty* or [VM0026 *Methodology for Sustainable Grasslands Management v1.1*](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf), Section 8.2.9 *Uncertainty Analysis*. Projects may use emerging technologies to track, monitor or measures indicators of SOC content if sufficient scientific progress has been achieved in calibrating and validating measurements, and uncertainty is understood. See Appendix 2.0 for examples of several emerging technologies.

Project Proponents may meet or exceed the Verra Standard confidence and uncertainty factors defined in [VM0042 *Methodology for Improved Agricultural Land Management, v2.0*](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf)*,* Section 8.6 *Uncertainty* or [VM0026 *Methodology for Sustainable Grasslands Management v1.1*](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf), Section 8.2.9 *Uncertainty Analysis* and utilize project statistically significant factors for SOC analysis and utilize emerging technologies per Appendix 3.0. Statistical confidence and uncertainty must be demonstrated at the appropriate spatial scale of the measurement method.

If the uncertainty is above the limit defined in Verra’s [VM0042 *Methodology for Improved Agricultural Land Management, v2.0*](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf)*,* Section 8.6 *Uncertainty* or [VM0026 *Methodology for Sustainable Grasslands Management v1.1*](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf), Section 8.2.9 *Uncertainty Analysis*, a Project Proponent would reduce the carbon removal assessment by the percentage of uncertainty exceeding the uncertainty determined in the applicable Verra Standard, unless a Project Proponent resolves the uncertainty by:

1. Utilizing [VMD0021 *Estimation of Stocks in the Soil Carbon Pool*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf)Step 6.5a and [TRS-1 *Methods to Determine Stratification*](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/)Step 7 or
2. Demonstrating statistically that the project falls within the uncertainty percentage for the applicable Verra Standard utilized by the Project Proponent.

As an example, lower cost flux towers have become available to measure annual mass balance of GHG’s over landscapes. Prior to accepting these new towers, a research team did two years of side-by-side testing on multiple ranches to see how the long-established flux tower and the lower cost units compared. These findings affirmed more durable and reliable data collection (less down time for maintenance) with the lower cost units, and comparable accuracy and precision during the concurrent data collection periods. The performance testing did, however, demonstrate the lower down time provided a more accurate estimation annual net change in GHG flux.

Quantification of Baseline Emissions from Non-Soil Carbon Sources

These tasks relate to quantification of emissions from sources other than soil carbon such as biomass carbon pools, CH4, N2O, etc. They are required for all projects where significant changes greater than 10% are expected for the baseline scenario at any time after the project start date; but are optional for other projects.

#### Project area stratification for biomass

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| --- | --- |
| Requirement | Required for all projects where the difference in total above and below-ground biomass carbon between the project scenario and the baseline scenario at any time after the project start date is expected to be significant. Optional for all other projects. |
| Goal | To divide the project area into one or more strata within which the existing vegetation carbon pools and vegetation dynamics are uniform. |
| Method | Use module [TRS-1 Methods to Determine Stratification](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/), with above and below-ground biomass stocks per unit area as the relevant variable X. |

#### Estimation of the carbon content of current above-ground woody and non-woody biomass and below-ground living biomass pools

|  |  |
| --- | --- |
| Requirement | Required for all projects where the difference in total above- and below-ground biomass carbon between the project scenario and the baseline scenario at any time after the project start date is expected to be significant. Optional for all other projects. |
| Goal | To sample the above-ground biomass pools and derive the below-ground biomass pool in each stratum with a sampling intensity sufficient to estimate at the required levels of statistical precision and accuracy, the amount of biomass carbon per unit area. |
| Method | Use module [TRS-4 Estimation of Carbon Stocks in Living Plant Biomass](https://verra.org/wp-content/uploads/imported/methodologies/VMD0022-Estimation-of-Carbon-Stocks-in-Living-Plant-Biomass-v1.0.pdf). |

#### Projection of future biomass pools under the baseline scenario

|  |  |
| --- | --- |
| Requirement | Required for all projects where the difference in total above and below-ground biomass carbon between the project scenario and the baseline scenario at any time after the project start date is expected to be significant. Optional for all other projects. |
| Goal | To determine the future changes in total biomass within the project area under the baseline scenario. |
| Method | Use module [TRS-2 Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf), with biomass pools as the relevant variable X. |

#### Estimation of the amount of current wood harvest from within the project area used for production of long-lived wood products

|  |  |
| --- | --- |
| Requirement | Required where the harvest of significant quantities (defined as greater than the amounts of woody biomass that currently die annually, and through natural decomposition release GHG quantities to the atmosphere) that are greater than the amounts of woody biomass currently occurs within the project area, or is expected to be regenerated annually in the future under the baseline scenario, and some or all of that woody biomass is used for the production of long lived wood products. Optional and not recommended in all other cases. |
| Goal | To estimate the current amount of woody biomass harvesting taking place within the project area. |
| Method | Use module [TRS-7 Estimation of Woody Biomass Harvesting and Utilization](https://verra.org/wp-content/uploads/imported/methodologies/VMD0025-Estimation-of-Woody-Biomass-Harvesting-and-Utilization-v1.0.pdf). |

#### Projection of future wood harvest outputs

|  |  |
| --- | --- |
| Requirement | Required where the harvest of significant amounts of woody biomass currently occurs within the project area or is expected to occur in the future under the baseline scenario, and some or all that woody biomass is used to produce long-lived wood products. Optional and not recommended in all other cases. |
| Goal | To project the most probable amount of woody biomass harvesting, and utilization of that harvest to produce long-lived wood products, which is expected to occur under the baseline scenario. |
| Method | Use module [TRS-2 Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf), with wood harvest and utilization for long-lived wood products as the relevant variable X. |

#### Long-lived wood products

|  |  |
| --- | --- |
| Requirement | Required where the harvest of significant amounts of woody biomass currently occurs within the project area or is expected to occur in the future under the baseline scenario, and some or all that woody biomass is used to produce long-lived wood products. Optional and not recommended in all other cases. |
| Goal | To project the amount of carbon which will be sequestered in long-lived wood products under the baseline scenario. |
| Method | Use module [TRS-8 Estimation of Carbon Stocks in the Long Lived Wood Products Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf), with the outputs from *[Task 2.2.4. Estimation of the amount of current wood harvest from within the project area used for production of long-lived wood products](#bookmark=kix.leqgwmagbqz4)* and *[Task 2.2.5 Projection of future wood harvest outputs](#bookmark=kix.m31vjx6hgjll)* as the inputs. |

#### Estimation of current dead wood pools within the project area

|  |  |
| --- | --- |
| Requirement | Required where there are significant amounts of dead wood in the project area at the project start date, and removals of dead wood through utilization, reduced inputs or accelerated burning as part of a management activity are expected to occur under the project scenario. Optional under all other circumstances. |
| Goal | To estimate the current amount of biomass contained in dead wood pools. |
| Method | Use module [TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0024-Estimation-of-Carbon-Stocks-in-the-Dead-Wood-Pool-v1.0.pdf). |

#### Projection of future dead wood pools within the project area

|  |  |
| --- | --- |
| Requirement | Required where there are significant amounts of dead wood in the project area at the project start date, and removals of dead wood through utilization, reduced inputs or accelerated burning as part of a management activity are expected to occur under the project scenario. Optional under all other circumstances. |
| Goal | To project the amount of biomass which will be contained in dead wood pools under the baseline scenario. |
| Method | Use module [TRS-2 Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf), with dead wood pools as the relevant variable X. |

#### Estimation of current average domesticated animal populations within the project area

|  |  |
| --- | --- |
| Requirement | Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances. |
| Goal | To estimate the average current population of domesticated animals within the project area. |
| Method | Use the module [TRS-9 Estimation of Emissions from Domesticated Animals](https://verra.org/wp-content/uploads/imported/methodologies/VMD0027-Estimation-of-Domesticated-Animal-Populations-v1.0.pdf). |

#### Projection of future domesticated animal populations under the baseline scenario

|  |  |
| --- | --- |
| Requirement | Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances. |
| Goal | To project the future populations of domesticated animals under the baseline scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with domesticated animal populations as the relevant variable X. |
| Comments | If at any time, within the project crediting period, the populations of domesticated animals under the baseline scenario are projected to be greater than those found at the project start date, populations at that time must be accounted as being equal to current levels. Conservatively, this methodology does not account for projected increases in animal populations and resulting emissions under the baseline scenario. |

#### Estimation of emissions of GHGs from domesticated animals within the project area under the baseline scenario

|  |  |
| --- | --- |
| Requirement | Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances. |
| Goal | To estimate GHG emissions from current and projected future domesticated animal populations under the baseline scenario. |
| Method | Use module [TRS-10](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf) *[Estimation of Emissions from Domesticated Animals](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf)*, with the outputs from *[Task 2.2.9. Estimation of current average domesticated animal populations within the project area](#bookmark=id.z151mgjdegnt)* and *[Task 2.2.10. Projection of future domesticated animal populations under the baseline scenario](#bookmark=id.qzet6i3mm2c9)* as the inputs. |

#### Estimation of current soil emissions of N2O or CH4 from within the project area

|  |  |
| --- | --- |
| Requirement | Required where emissions of N2O or CH4 from the soils within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances. |
| Goal | To estimate the current emissions of N2O or CH4 from within the project area. |
| Method | Use module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Emissions of Non-CO2 GHGs from Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*. |

#### Projection of future emissions of N2O or CH4 from the soils within the project area

|  |  |
| --- | --- |
| Requirement | Required if, at any time within the project crediting period, the emissions of N2O or CH4 from the soils within the project area under the baseline scenario are projected to be greater than those found under the project scenario. Optional under all other circumstances. |
| Goal | To project future emissions from soils under the baseline scenario, in the case that these emissions are expected to decline. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with relevant input variable(s) from the module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non CO2 GHG from Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*, as the relevant variable(s) X. Then, based on the outputs from this module, use the module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non-CO2 GHG from Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)* to estimate the projected future emissions. |

#### Projected emissions from use of power equipment

|  |  |
| --- | --- |
| Requirement | Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario. |
| Goal | To project GHG emissions for the monitoring period from the use of power equipment under the baseline scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to activities within the project area are all accounted as baseline or project emissions, whether the actual emissions occur within the project area. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with fuel uses in power equipment as the relevant variable(s) X. Then, based on the outputs from this module, use the module [TRS-12](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf) *[Estimation of Emissions from Power Equipment](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf)* to estimate the projected future emissions. |

#### Estimation of current litter pools

|  |  |
| --- | --- |
| Requirement | Required where significant decreases in litter pools within the project area are expected under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances. |
| Goal | To estimate the carbon content of the litter pool within the project area. |
| Method | Use module [TRS-5](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Litter Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf)*. |

#### Projection of future litter pools

|  |  |
| --- | --- |
| Requirement | Required where significant decreases in litter pools within the project area are expected under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances. |
| Goal | To project emissions from future litter pools under the baseline scenario where these emissions are expected to decline under the baseline scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with relevant input variable(s) from the module [TRS-5](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Litter Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf)*, as the relevant variable(s) X. |
| Comments | If, at any time in the project crediting period, the litter pools within the project area under the baseline scenario are projected to be less than those at the project start date, litter pools for that time must be accounted as being equal to levels at the project start date. Conservatively, this methodology does not account for projected decreases in litter pools under the baseline scenario. |

#### Summation of estimates and projections under the baseline scenario

|  |  |
| --- | --- |
| Requirement | Required for all projects for which changes greater than 10% are expected in any non-soil carbon pool or other GHG emission, otherwise optional. |
| Goal | To sum current and future carbon sequestration and emissions under the baseline scenario. |
| Method | Use module: [TRS-17](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf)*. |

### Ex-ante Projections of Project Emissions from Non-soil Carbon Sources

These tasks relate to quantification of projected emissions from sources other than soil carbon during the project periods related to changes in biomass carbon pools, CH4, N2O, etc.

#### Projection of future above-ground woody and non-woody and below-ground living biomass pools under the project scenario

|  |  |
| --- | --- |
| Requirement | Required for all projects where significant decreases in living biomass pools are expected to occur under the project scenario, as compared with the baseline scenario. Optional in all other circumstances. |
| Goal | To project for the monitoring period the above-ground woody and non-woody biomass and below-ground living biomass pools in each stratum based on expected treatment regimes, and to estimate the amount of living biomass carbon per unit area based on those projections. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with live biomass as the relevant variable X and the module [TRS-4](https://verra.org/wp-content/uploads/imported/methodologies/VMD0022-Estimation-of-Carbon-Stocks-in-Living-Plant-Biomass-v1.0.pdf) *[Estimation of Carbon Stocks in Living Plant Biomass](https://verra.org/wp-content/uploads/imported/methodologies/VMD0022-Estimation-of-Carbon-Stocks-in-Living-Plant-Biomass-v1.0.pdf)*. |

#### Projection of future wood harvest outputs under the project scenario

|  |  |
| --- | --- |
| Requirement | Required for all projects where the harvest of woody biomass within the project area is expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period and some or all that woody biomass is used to produce long-lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional, but not recommended, where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario as compared with the baseline scenario. |
| Goal | To project for the monitoring period the amount of woody biomass harvesting which is expected to take place within the project area under the project scenario, and the percentage of that harvest which is expected to be used to produce long-lived wood products. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with wood harvest and wood utilization as the relevant variable X. |

#### Projection of carbon sequestration in long-lived wood products

|  |  |
| --- | --- |
| Requirement | Required for all projects where the harvest of woody biomass within the project area is expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period and some or all that woody biomass is used to produce long lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional, but not recommended, where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario as compared with the baseline scenario. |
| Goal | To estimate the amount of carbon which will be sequestered in long-lived wood products under the project scenario, based on the projections prepared in *[Task 2.3.4 Projection of future wood harvest outputs under the project scenario](#bookmark=kix.tuc061xb50jc)*. |
| Method | Use module [TRS-8](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf)*, with the outputs from *[Task 2.3.2 Projection of future wood harvest outputs under the project scenario](#bookmark=kix.tuc061xb50jc)* as the inputs. |

#### Projection of future dead wood pools within the project area under the project scenario

|  |  |
| --- | --- |
| Requirement | Required where significant amounts of dead wood are found on the site at the project start date, and removals of dead wood through utilization, reduced inputs, or accelerated burning as part of management activity, are expected to occur under the project scenario. Optional in all other circumstances. |
| Goal | To estimate the amount of biomass which will be sequestered in dead wood pools under the project scenario. |
| Method | Use the module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with dead wood pools as the relevant variable X. |

#### Projection of future domesticated animal populations under the project scenario

|  |  |
| --- | --- |
| Requirement | Required where increases in the emissions of GHGs from domesticated animal populations are expected under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for projected decreases in emissions from domesticated animals under the project scenario as compared with the baseline scenario. |
| Goal | To project the future populations of domesticated animals for the monitoring period under the project scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with domesticated animal populations as the relevant variable X. |

#### Estimation of emissions of GHGs from domesticated animals within the project area under the project scenario

|  |  |
| --- | --- |
| Requirement | Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances. |
| Goal | To estimate the emissions of GHGs from the current and projected future populations of domesticated animals under the project scenario the monitoring period based on the projections prepared in *[Task 2.3.5. Projection of future domesticated animal populations under the project scenario](#bookmark=id.2zndxyka71qh)*. |
| Method | Use module [TRS-9](https://verra.org/wp-content/uploads/imported/methodologies/VMD0027-Estimation-of-Domesticated-Animal-Populations-v1.0.pdf) *[Estimation of Emissions From Domesticated Animals](https://verra.org/wp-content/uploads/imported/methodologies/VMD0027-Estimation-of-Domesticated-Animal-Populations-v1.0.pdf)*, with the outputs from *[Task 2.3.5. Projection of future domesticated animal populations under the project scenario](#bookmark=id.2zndxyka71qh)* as the inputs. |

#### Projection of future emissions of N2O or CH4 from the soils within the project area

|  |  |
| --- | --- |
| Requirement | Required where significant increases in the emissions of N2O or CH4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances. |
| Goal | To estimate future emissions from soils under the project scenario, in the case that these emissions are expected to increase. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with relevant input variable(s) from the module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non CO2 GHG From Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*, as the relevant variable(s) X. Then, based on the outputs from this module, use the module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non CO2 GHG From Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*, to estimate the projected future emissions. |

#### Projected emissions from use of power equipment

|  |  |
| --- | --- |
| Requirement | Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario. |
| Goal | To estimate GHG emissions for the monitoring period from the use of power equipment under the project scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted for as project emissions, whether they occur within the project boundary. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with fuel use in power equipment as the relevant variable(s) X. Then, based on the outputs from this module, use the module [TRS-12](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf) *[Estimation of Emissions from Power Equipment](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf)*, to estimate the projected future emissions. |

#### Projection of future litter pools

|  |  |
| --- | --- |
| Requirement | Required where significant decreases in the carbon content of the litter carbon pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances. |
| Goal | To estimate future litter pools under the project scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with litter carbon pools as the relevant variable X. |

#### Projection of biomass consumption by fire

|  |  |
| --- | --- |
| Requirement | Required where significant burning is expected to be used for management of the project area under the project scenario. Optional but not recommended otherwise. |
| Goal | To project the future amounts of biomass consumed by fire during the project crediting period under the project scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with biomass consumed by fire as the relevant variable X. |
| Comments | This step shall be done twice if biomass burning is to be done both within the project area, and outside of the project area because of displacement leakage. In that case, the results will be used for separate calculations during *[Task 2.5.2. Projection of leakage due to displacement of wood harvesting](#bookmark=kix.4vx95xnnhrkc)*. |

#### Projection of non CO2 emissions from burning

|  |  |
| --- | --- |
| Requirement | Required where significant burning is expected to be used for management of the project area under the project scenario. Optional but not recommended otherwise. |
| Goal | To estimate emissions of non CO2 GHGs from burning of biomass. |
| Method | Use module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non CO2 GHG from Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*. |
| Comments | This step shall be done twice if biomass burning is done both within the project area, and outside of the project area because of activity shifting leakage. In that case, the results will be reported and accounted for separately during *[Task 2.3.12 Projection of biomass consumption by fire](#bookmark=kix.mm8499lj8ux9)*, above. |

#### Summation of ex-ante project scenario emissions from sources other than soil carbon (e.g., biomass carbon pools, CH4, N2O, etc.)

|  |  |
| --- | --- |
| Requirement | Required for all projects. This will be zero for projects with no projected changes in emissions from sources other than soil carbon (e.g., biomass carbon pools, CH4, N2O, etc.). If non-zero, appropriate adjustment must be made to interim crediting. |
| Goal | To sum current and future carbon sequestration and emissions under the project scenario. |
| Method | Use module [TRS-17](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf)*, setting leakage variables to 0, as these will be accounted for in *[Task 2.6. Ex-post Quantification of Project Leakage](#bookmark=id.6bkwqoo2mjyg)*. |

### Ex-post Quantification of Project Emissions

Ex-post accounting of GHG pools and emissions must be undertaken prior to each verification event, and at least once every five (5) years during the project crediting period. Note that where leakage mitigation measures include tree planting, agricultural intensification, fertilization, fodder production, and/or other measures to enhance cropland and/or grazing land areas, then any significant increase in GHG emissions associated with these activities must be accounted for using the relevant module, whether or not they occur within the project area, unless they are deemed not significant, or can otherwise be conservatively excluded. To determine the ex-post quantification of GHG pools and emissions in the project area, the Project Proponent should use the following steps, as applicable:

#### Estimation of the carbon content of current soil carbon pools per unit of area, for each stratum

|  |  |
| --- | --- |
| Requirement | Required for all projects. |
| Goal | To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to allow estimation, at the required levels of statistical precision and accuracy, of the amount of soil carbon per unit area. |
| Method | Use module [VMD0021](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf) *[Estimation of Stocks in the Soil Carbon Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0021-Estimation-of-Stocks-in-the-Soil-Carbon-Pool-v1.0.pdf)*. |

#### Estimation of the carbon content of above-ground woody and non-woody and below-ground living biomass pools

|  |  |
| --- | --- |
| Requirement | Required for all projects where the above-ground woody and non-woody biomass and below-ground living biomass carbon under the project scenario is found to be significantly less than that projected under the baseline scenarios at any time after the project start date. Optional under all other circumstances. Typically, completion of this task will be required where the project area before the project start date contains more than scattered woody vegetation, and where the project activities include clearance, site preparation, burning, or other activities likely to eliminate woody vegetation, or alternatively to enhance the recruitment of woody vegetation. |
| Goal | To sample the above-ground woody and non-woody biomass and below-ground living biomass pools in each stratum to a sampling intensity sufficient to allow estimation to the required levels of statistical precision and accuracy of the amount of living biomass carbon per unit area. |
| Method | Use module [TRS-4](https://verra.org/wp-content/uploads/imported/methodologies/VMD0022-Estimation-of-Carbon-Stocks-in-Living-Plant-Biomass-v1.0.pdf) *[Estimation of Carbon Stocks in Living Plant Biomass](https://verra.org/wp-content/uploads/imported/methodologies/VMD0022-Estimation-of-Carbon-Stocks-in-Living-Plant-Biomass-v1.0.pdf)*. |

#### Estimation of the amount of wood harvest from within the project area used to produce long-lived wood products

|  |  |
| --- | --- |
| Requirement | Required for all projects where the harvest of woody biomass within the project area is expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period, and some or all that woody biomass is used to produce long-lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional but not recommended in the case where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario, as compared with the baseline scenario. |
| Goal | To estimate the amount of woody biomass harvesting taking place within the project area during a monitoring period. |
| Method | Use module [TRS-7](https://verra.org/wp-content/uploads/imported/methodologies/VMD0025-Estimation-of-Woody-Biomass-Harvesting-and-Utilization-v1.0.pdf) *[Estimation of Woody Biomass Harvesting and Utilization](https://verra.org/wp-content/uploads/imported/methodologies/VMD0025-Estimation-of-Woody-Biomass-Harvesting-and-Utilization-v1.0.pdf)*. |

#### Long-lived wood products

|  |  |
| --- | --- |
| Requirement | Required for all projects where the harvest of woody biomass within the project area is expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period, and some or all that woody biomass is used to produce long-lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional but not recommended in the case where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario, as compared with the baseline scenario. |
| Goal | To project the amount of carbon that will be sequestered in long-lived wood products derived from harvesting from within the project area during the monitoring period. |
| Method | Use module [TRS-8](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf)*, with the outputs from *[Task 2.4.3. Estimation of the amount of wood harvest from within the project area used for the production of long-lived wood products](#bookmark=id.eha5ml8c0o18)* as the inputs. |

#### Estimation of dead wood pools within the project area

|  |  |
| --- | --- |
| Requirement | Required where dead wood is found on the site at the project start date, and significant removals of dead wood through utilization, reduced inputs, or accelerated burning as part of a management activity, are expected to occur under the project scenario. Optional under all other circumstances. |
| Goal | To estimate the current amount of biomass contained in dead wood pools. |
| Method | Use module [TRS-6](https://verra.org/wp-content/uploads/imported/methodologies/VMD0024-Estimation-of-Carbon-Stocks-in-the-Dead-Wood-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Dead Wood Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0024-Estimation-of-Carbon-Stocks-in-the-Dead-Wood-Pool-v1.0.pdf)*. |

#### Estimation of average domesticated animal populations within the project area

|  |  |
| --- | --- |
| Requirement | Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baseline scenario, due either to increases in populations or changes in feeding practices., Optional under all other circumstances. |
| Goal | To estimate the average current populations of domesticated animals within the project area during the monitoring period. |
| Method | Use module [TRS-10](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf) *[Estimation of Emissions from Domesticated Animals](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf)*. |

#### Estimation of emissions of GHGs from domesticated animals within the project area

|  |  |
| --- | --- |
| Requirement | Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baseline’s scenario, due either to increases in populations or changes in feeding practices. Not for use under all other circumstances, to conservatively ensure that crediting for reductions in emissions from domesticated animals does not occur. |
| Goal | To estimate the emissions of GHGs from the current populations of domesticated animals during the monitoring period. |
| Method | Use module [TRS-10](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf) *[Estimation of Emissions from Domesticated Animals](https://verra.org/wp-content/uploads/imported/methodologies/VMD0028-Estimation-of-Emissions-from-Domesticated-Animals-v1.0.pdf)*, with the outputs from *[Task 2.4.6.Estimation of current average domesticated animal populations within the project area](#bookmark=id.awht17ee5sb)* as inputs. |

#### Estimation of emissions from use of power equipment

|  |  |
| --- | --- |
| Requirement | Required for all projects where emissions from power equipment directly attributable to activities within the project area could be significantly greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario. |
| Goal | To estimate GHG emissions from the use of power equipment under the project scenario during the monitoring period. |
| Method | Use module [TRS-12](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf) *[Estimation of Emissions from Power Equipment](https://verra.org/wp-content/uploads/imported/methodologies/VMD0030-Estimation-of-Emissions-from-Power-Equipment-v1.0.pdf)*. |
| Comments | Under this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted as a project emission, whether they occur within the project boundary. |

#### Estimation of non CO2 emissions from burning

|  |  |
| --- | --- |
| Requirement | Required where significant burning has been used for management of the project area under the project scenario. Optional but not recommended under all other circumstances. |
| Goal | To estimate emissions of non CO2 GHGs from burning of biomass. |
| Method | Use module [TRS-13](https://verra.org/wp-content/uploads/imported/methodologies/VMD0031-Estimation-of-Emissions-from-Burning-v1.0.pdf) *[Estimation of Emissions from Burning](https://verra.org/wp-content/uploads/imported/methodologies/VMD0031-Estimation-of-Emissions-from-Burning-v1.0.pdf)*. |
| Comments | This step must be done twice if biomass burning is done both within the project area and outside of the project area because of displacement leakage. In that case, the results will be reported and accounted separately during *[Task 2.5.2. Projection of leakage due to displacement of wood harvesting](#bookmark=kix.4vx95xnnhrkc)* and/or *[Task 2.6.2. Monitoring and estimation of emissions from wood harvest displacement](#bookmark=id.cknmdenmgyfg)*. |

#### Monitoring and estimation of soil emissions of N2O or CH4 from within the project area

|  |  |
| --- | --- |
| Requirement | Required where significant increases in the emissions of N2O or CH4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances. |
| Goal | To estimate the emissions of N2O or CH4 from within the project area. |
| Method | Use module [TRS-11](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf) *[Estimation of Emissions of Non-CO2 GHG from Soils](https://verra.org/wp-content/uploads/VMD0029-Estimation-of-Emissions-of-nonCO2-GHGs-from-Soils-v1.1.pdf)*. |
| Comments | These estimations are expected to be based on the same models as those used during the ex-ante project study unless improvements in models have occurred in the interim. In either case, values of variables used in the models must be updated to reflect actual conditions which have occurred during the monitoring period. If an updated model is used, and if modeling of baseline emissions was done as part of the baseline study, that modeling must be redone using the improved models. |

#### Estimation of litter pools

|  |  |
| --- | --- |
| Requirement | Required where significant decreases in the carbon content of the litter pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances. |
| Goal | To estimate the carbon content of the litter pool within the project area. |
| Method | Use module [TRS-5](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Litter Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0023-Estimation-of-Carbon-Stocks-in-the-Litter-Pool-v1.0.pdf)*. |

#### Summation of ex-post project emissions from sources other than soil carbon (e.g., biomass carbon pools, CH4, N2O, etc.)

|  |  |
| --- | --- |
| Requirement | Required for all projects. |
| Goal | To sum carbon sequestration and emission impacts directly attributable to the project activity based on the monitoring undertaken during the monitoring period. |
| Method | Use module [TRS-17](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities](https://verra.org/wp-content/uploads/imported/methodologies/VMD0035-Methods-to-Determine-the-Net-Change-in-Atmospheric-GHG-Resulting-from-Project-Activities-v1.0.pdf)*, setting leakage variables to 0. |

### Ex-ante Projection of Leakage

If it is likely the project activities will lead to an increase in GHG emissions by more than 10% during the project period (see [*Table 1. Likelihood of project activities leading to an increase in GHG emissions during the project period*](#bookmark=id.9k5al5dkiacu) above), the Project Proponent should use the following steps, as applicable.

#### Projection of leakage due to displacement of grazing, fodder, and agricultural production

|  |  |
| --- | --- |
| Requirement | Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities are projected to decline within the project area due to project activities. |
| Goal | To project future emissions from agricultural production, domesticated animals or fodder production displaced under the project scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with displacement of domesticated animals or agricultural production as the relevant variable(s) X. Then, based on the outputs from this module, use module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, to estimate the impacts. Depending on the results from the module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, calculations of emissions may require the use of other modules. |

#### Projection of leakage due to displacement of wood harvesting

|  |  |
| --- | --- |
| Requirement | Required for projects where displacement of wood harvest to areas outside of the project boundary is projected to occur. |
| Goal | To project future emissions from wood harvest displaced under the project scenario. Projection includes the reductions in emissions from these displaced wood harvest activities where they are expected to result in the production of long-lived wood products. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)*, with displacement of wood harvest as the relevant variable(s) X. Then, based on the outputs from this module, use module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, to estimate the impacts. Depending on the results from module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, calculations of emissions may require the use of other modules. |
| Comments | Where wood harvesting occurs outside of the project boundary as a result of activity shifting leakage, and where that wood harvesting results in the production of long-lived wood products, module [TRS-8](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf)* must be used to estimate the amounts of carbon stored in wood products resulting from the wood harvesting. |

#### Projection of market leakage

|  |  |
| --- | --- |
| Requirement | Required for projects where reductions in the production of wood, animals or agricultural products within the project area are expected under the project scenario as compared with the baseline scenario, and where *[Task 2.5.1. Projection of leakage due to displacement of grazing, fodder, and agricultural production](#bookmark=kix.wfcy78bh5q21)* and *[Task 2.5.2. Projection of leakage due to displacement of wood harvesting](#bookmark=kix.4vx95xnnhrkc)* do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area. |
| Goal | To project leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario |
| Method | Use module [TRS-15](https://verra.org/wp-content/uploads/imported/methodologies/VMD0033-Estimation-of-Emission-from-Market-Leakage-v1.0.pdf) *[Estimation of Emissions from Market Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0033-Estimation-of-Emission-from-Market-Leakage-v1.0.pdf)*. |

### Ex-post Quantification of Project Leakage

#### Monitoring and estimation of emissions from grazing, fodder, and agricultural production displacement

|  |  |
| --- | --- |
| Requirement | Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities have declined within the project area due to project activities. |
| Goal | Estimation of emissions from domesticated animals or fodder production displaced because of project activities during the crediting period. |
| Method | Use module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, to estimate the impacts. Depending on the results from the module, calculations of emissions may require the use of other modules. |

#### Monitoring and estimation of emissions from wood harvest displacement

|  |  |
| --- | --- |
| Requirement | Required for projects where wood harvest occurred within the project area at the project start date, and where total wood harvest from the project area over the monitoring period will decline as compared with that projected under the baseline scenario. |
| Goal | Estimation of emissions from wood harvesting displaced because of project activities during the crediting period. |
| Method | Use module [TRS-14](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf) *[Estimation of Emissions from Activity-Shifting Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0032-Estimation-of-Emissions-from-Activity-Shifting-Leakage-1.0.pdf)*, to estimate the impacts. Depending on the results from the calculations of emissions may require the use of other modules. Where displaced wood harvesting results in the production of long-lived wood products, module [TRS-8](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool](https://verra.org/wp-content/uploads/imported/methodologies/VMD0026-Estimation-of-Carbon-Stocks-in-the-Long-Lived-Wood-Products-Pool-v1.0.pdf)*, must also be used. |

#### Estimation of market leakage

|  |  |
| --- | --- |
| Requirement | Required for projects where reductions in the production of wood, animals, or agricultural products within the project area have occurred under the project scenario, as compared with the baseline scenario, and where *[Task 2.6.1. Monitoring and estimation of emissions from grazing, fodder, and agricultural production displacement](#bookmark=id.rr6jkl4kugg6)* and *[Task 2.6.2. Monitoring and estimation of emissions from wood harvest displacement](#bookmark=id.cknmdenmgyfg)* do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area. |
| Goal | To estimate leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario. |
| Method | Use module [TRS-15](https://verra.org/wp-content/uploads/imported/methodologies/VMD0033-Estimation-of-Emission-from-Market-Leakage-v1.0.pdf) *[Estimation of Emissions from Market Leakage](https://verra.org/wp-content/uploads/imported/methodologies/VMD0033-Estimation-of-Emission-from-Market-Leakage-v1.0.pdf)*. |
| Comments | If market leakage has been projected in *[Task 2.1 Quantification of Soil Carbon Stocks for Baseline and Project Scenarios](#bookmark=kix.1ksc8fceh79e)* and *[Task 2.2 Quantification of Baseline Emissions from Non-Soil Carbon Sources](#bookmark=kix.mwhsaopv4b6h)*, and if the input conditions remain the same ex-post as those predicted ex-ante, the projections completed in *[Task 2.3.12 Summation of ex-ante project scenario emissions from sources other than soil carbon (e.g. biomass carbon pools, CH4, N2O, etc.)](#bookmark=kix.hneywso7jxy)* may be used to satisfy the requirements of this task. |

### Monitoring

The Project Proponent must describe following [TRS-16 *Methods for Developing a Monitoring Plan*](https://verra.org/wp-content/uploads/imported/methodologies/VMD0034-Methods-for-Developing-a-Monitoring-Plan-v1.0.pdf) under the guidance of the [VCS Validation and Verification Manual, v3.2](https://verra.org/wp-content/uploads/2018/03/VCS_Validation_Verification_Manual_v3.2.pdf) how “the entire project longevity must be covered by management and financial plans that demonstrate the intention to continue the management practices.” The monitoring plan must also include annual proof of activity. For any Project Proponent executing [*Task 3 Interim Crediting Assessment (Optional)*](#bookmark=id.5cie6kuirofq), any sample handling or SOC results that might have been received in the interim period must also be documented.

## Interim Crediting Assessment (Optional)

The generation of high-quality data is the foundation of TRS SOC. This quality is ensured through soil sampling and analysis to one meter depth (or to refusal) with a measure-remeasure approach, from baseline (T0) to follow-up (T1) timepoints spanning the duration of project. To incentivize rancher, farmer, conservationist, and project developer participation, TRS SOC allows for optional methods to estimate annual SOC accrual between the baseline (T0) and subsequent true-up date (T1) measurements. This forward-looking assessment of interim carbon credits aims to provide pre-T1 revenue for farmers, ranchers, and other Land Stewards to overcome financial challenges to implementing improved agricultural management practices, and to incentivize the adoption of improved agricultural, conservation and restorative land management practices and enhance the quality of the carbon credits generated by TRS SOC.

Forward-looking assessments for interim crediting are not a replacement for direct measurement (and the measure-to-measure quantification) of SOC at the beginning and end of the project period. All forward-looking assessments for interim crediting are required to be substantiated by 1-meter deep (or to refusal), direct soil sampling to establish the baseline (T0) soil organic carbon with subsequent (T1) deep sampling collected within an average of five to seven years to true-up the project soil carbon sequestration.

### Projection of future soil carbon accrual rate for the project scenario

|  |  |
| --- | --- |
| Requirement | Required for all projects applying for interim carbon credits. |
| Goal | To project the future soil organic carbon sequestration rate (“accrual rate”) per unit area for each projected verification date within the project crediting period under the project scenario. |
| Method | Use module [TRS-2](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf) *[Methods to Project Future Conditions](https://verra.org/wp-content/uploads/imported/methodologies/VMD0019-Methods-to-Project-Future-Conditions-v1.0.pdf)* |
| Comments |  |

Table 1. Will have been used prior to affirm the key factors that drive change with the proposed activity change(s) by a project. The use of Table 1 (See Task 2) helps determine the prediction of variable change, degree of certainty for this prediction, and interrelations of variables resulting from the proposed activity. This information is further evaluated with a focus on soil carbon changes.

The module TRS-2 provides a step-by-step approach to assess the key factors that drive change in future soil organic carbon accrual rates and provides a suite of methods and approaches for projecting future conditions, as well as decision criteria for choosing the most appropriate method.

The following follows the application of module TRS-2 for the estimation of soil organic carbon accrual rates for the purpose of interim crediting, *using as a particular example*, a project involving regenerative grazing management practices:

Step 1, the variable to be projected is **soil organic carbon sequestration** (i.e., the SOC accrual rate) and the geographic area is the ranch **project boundary**.

Step 2, the accrual rate is to be projected under the **project scenario**.

Step 3, the accrual rate is **location specific**, because the rate depends on the variability of the weather conditions throughout the growing season and the underlying soil conditions across the location of the ranch. Additionally, the accrual rate is largely **systemic**, because changes in its value depend primarily on many factors outside of local control (e.g. weather), although other aspects determining the accrual rate may be considered planned (e.g. adaptive multi paddock grazing, low intensity rotational grazing, etc.) or controlled (e.g. reduce grazing intensity by 25%), depending on the particular project scenario.

Step 4, the accrual rate is considered **intended**, because it arises because of the project activities under the project scenario (e.g., increasing soil health and soil carbon through regenerative grazing management).

Step 5, the steps, or scenario that contribute to a future SOC accrual rate(s) include:

First – ***Primary Productivity***: Weather conditions, including rainfall (by extension, soil moisture)*,* temperature, solar radiation, and relative humidity, as well as soil nutrient availability, define the upper limit to potential rates of grassland primary productivity (i.e., biomass production) at a given location.

Second – Deposition: Plant organic matter because of primary productivity is deposited on or within the soil, from leaf and stem litter residue deposited on the soil surface to root litter and root exudates deposited as rhizodeposition in the root zone extending near the surface to the deepest rooting depths. Aboveground versus belowground allocation of carbon by plants is influenced by the relative aboveground and belowground environmental limitations to growth (e.g., greater allocation to belowground roots to acquire more water if soil moisture is most limiting).

Third – ***Decomposition***: Plant residues are broken down and decomposed by soil fauna (dung beetles, earthworms, ants, etc.) and microorganisms (e.g. fungi and bacteria), with organic matter on or near the soil surface typically decomposing faster and more completely than organic matter deposited deeper in the soil profile as root litter, as conditions near the soil surface generally have greater oxygen concentrations, higher temperatures and the looser soil structure that provide a more conducive environment for decomposition. The rate of decomposition is primarily driven by temperature and soil moisture and by the chemical composition or decomposability of organic matter. Plant organic matter is broken down into particulate organic matter (plant organic matter at various stages of decomposition) and organic matter of microbial origin (e.g., microbial neuromas). Microbial efficiency for decomposition is determined by the soil environmental conditions during decomposition (e.g., soil temperature and moisture) as well as by the decomposability of the organic matter substrate, itself influenced by the soil environmental conditions during production (e.g., influencing the allocation to different stress-response compounds).

Fourth – ***Dispersal***: Organic matter is physically dispersed throughout the soil profile, both vertically and laterally, from its sources near the soil surface or proximal to the rhizosphere of the roots, with a rate and efficiency of diffusion that is dictated by the availability of water in the soil.

Fifth – ***Stabilization***: Finally, SOC can be stored in the soil as relatively unprotected particulate organic matter (POM) or as chemically-protected mineral associated organic matter (MAOM), as well as physically-protected organic matter within soil aggregates. MAOM increases with soil clay and silt content and is nearly exclusively microbial-derived (necromass) with fungi playing a dominant role, and both physical and chemical protection make the organic matter largely inaccessible to decomposition by microorganisms, with MAOM in a more stable form of soil organic carbon (SOC) that is more resistant to decay even after physical disturbance of the soil such as by tilling.

Step 6, Following the procedures of TRS-2 (see TRS-2 Section 5 - Procedures) for **systemic, location specific** variables, proceed to Step 7.

Step 7, the SOC accrual rate is **not directly accessible through remote sensing**.

Step 7a, collation and analysis of existing data indicate there is **no historical record of SOC accrual rates in the analysis area**, proceed to Step 13.

Step 13, lacking any existing or historical trajectory of change in SOC accrual rates, **future values are modeled by considering the integration of multiple drivers, agents and causes on the accrual rate**. This approach for forecasting accrual rates is data intensive, with the data necessary to determine casual relationships between accrual rates and the various drivers, agents and causes drawn from the **best available peer reviewed scientific literature at the time of the project**, with **clear documentation** of the methods and data, including the **risks and uncertainties** in the variables used to make the projection, to ensure **conservative** **estimates.**

Step 13d.1: Current conditions of driving variables drawn from published and/or reliable data sources (e.g., **gridded precipitation and temperature, digital maps of soil clay and silt content, digital elevation models and topographic data, digital maps of soil thickness**, pH, cation exchange capacity, etc.)

Step 13d.2: Correlate SOC accrual rates with driving variables based on the findings of published literature (e.g. **increasing productivity with precipitation1, increasing microbial efficiency and SOC storage with precipitation2, increasing decomposition and decreasing SOC storage with precipitation3, increasing dispersal and SOC storage with precipitation4, increasing SOC storage with decreasing temperature5, increasing SOC storage with soil clay and silt content6, increasing SOC storage with soil thickness7, decreasing SOC storage with slope,** **increasing SOC storage with improved grazing management**8, etc.).

1Del Grosso et al. 2008: *Ecology*, 89(8):2117-212; 2Anthony et al. 2020: *One Earth*, 2:349–360; 3Parton et al. 1993: *Global Biogeochem Cycles*, 7(4):785-809; 4Heckman et al. 2023: *PNAS*, 120(7):e2210044120; 5Hartley et al. 2021: *Nature*, 12:6713; 6Georgiou et al. 2022: *Nature*, 13:3797; 7Jobbagy and Jackson 2000, *Ecol. Appl.* 10(2):423–36, 8Conant et al. 2017, *Ecological Applications*, 27(2): 662–668.

Step 13d.3: Model potential SOC accrual rates based on the aforementioned correlations, e.g. using a pragmatic approach, with the potential SOC accrual rate estimated as the potential net primary productivity (gC/m2/yr) and adjustment factors representing the relative probability (with a value ranging from 0-1) of SOC storage based on the most limiting factor (e.g. Law of the Minimum8) among a multitude of potentially limiting factors (e.g. **MAP, MAT, soil clay and silt content, topographic slope, soil thickness**, pH, cation exchange capacity, rock fragment content, C3/C4 fraction, tree cover fraction, annual/perennial fraction, fungal/bacteria ratio, etc.). 8Lieth, H. 1972. Modeling the primary productivity of the world, 10 pp., Deciduous Forest Biome Memo Rep. 72-9, March 1972.

Step 13d.4: Review and re-parameterize the model if predictions are improbable or show discrepancies compared to actual conditions (e.g., **adjust the maximum SOC accrual rate so estimates are consistent with literature values**)

Step 13d.5: Project future SOC accrual rates using conservative estimates for model drivers or model projections (e.g., **lower quartile of range for model predictions at a given location**)

Step 13d.6: Create a time series to **predict SOC accrual rates during the years of the project**.

## Project Application Submission

A Project Proponent interacts with the Nature’s Registry to list pipeline projects, register projects, and issue carbon credits. Prior to these interactions, the Project Proponent must open an account and submit all required credentials to the Nature’s Registry to submit projects for pipeline listing, verification, and registration. The full scope of the required project documentation for each property, for the entire credit origination including Idea note if a preapplication discussion is to be the focus with the registry and verifier, or a Project design plan, measurement and monitoring plan, and the content of each document as required in the verification and registry checklists as needed for a project to submit for crediting considerations (See definitions, project activity, life, project registration, verification and validation, project verification period, etc.). , Once a proponent project registration occurs with the Registry, , the project application process can begin.

**Figure 2: Opening a Nature’s Registry account:**

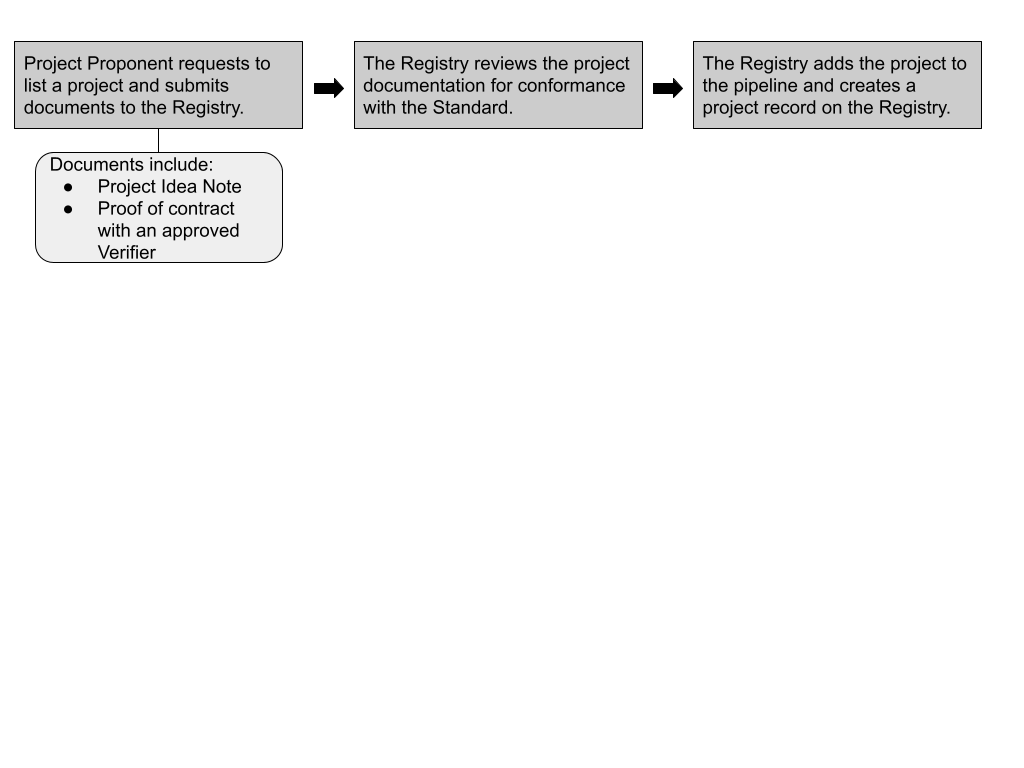


Note that all Verifiers must also complete an account application and submit all required credentials to the Nature’s Registry prior to verifying carbon projects (See [Verifier Prequalification](#VVB_prequal) requirements, in Appendix 2).

Approved Project Proponents must initiate the project application with the pipeline listing process by submitting to the Registry the following:

* A Project Idea Note that includes at minimum a cover page and drafts of Task 1 Project Overview - Identification and Eligibility of Project Activity and related sub-tasks.
* Proof of contract intent (such as a draft contract) or executed contract with an approved Verifier.

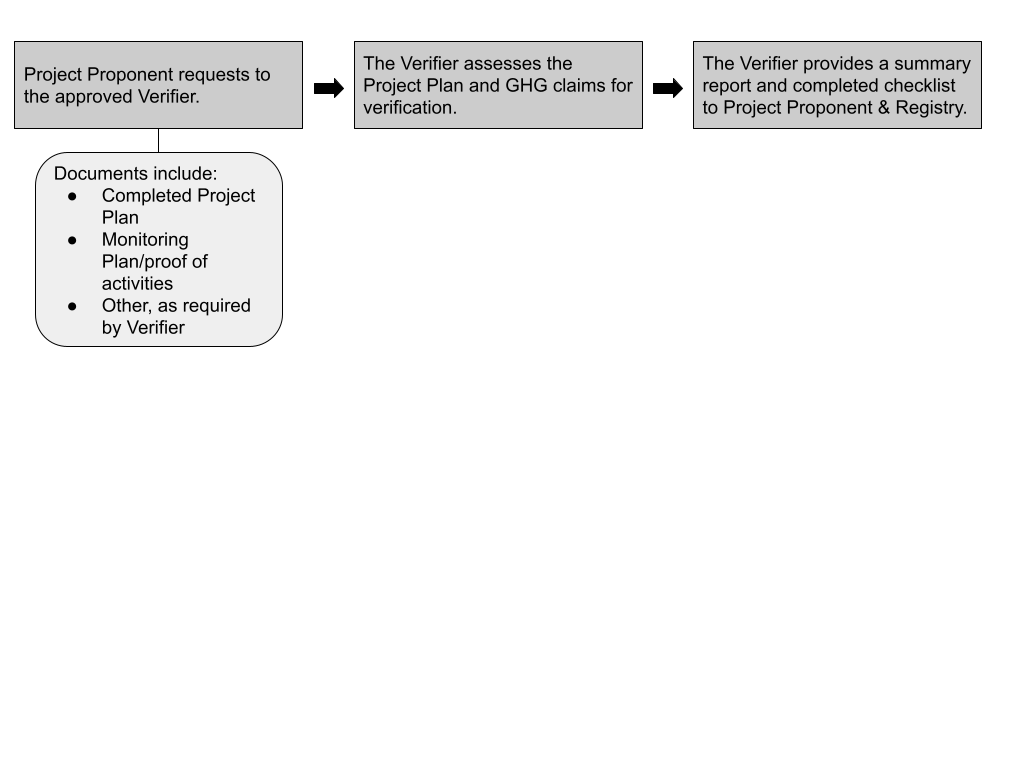
**Figure 3: Listing a project on the Nature’s Registry project pipeline:**



Once the project is listed with the Registry, a Project Proponent can complete the project application by submitting all documentation within a Project Plan to the approved Verifier to execute *Task 5. Verification*. A complete project application includes the Project Plan with the results from Tasks 1-3 in TRS SOC V2.0 with accompanying documentation within appendices that may include the following:

* Site maps
* Contracts
* Proof of Legal Ownership and County Appraisal District Tax Records
* Lessee/Lessor agreements (Control of the Land-Type Contracts)
* Stratification and Sampling Maps
* Supporting documentation for land management activities (Land Steward Surveys, Communications, etc.)
* Chain of custody documentation from soil analytics laboratory
* References

**Figure 4: Submitting a Project Plan for Verification:**



## Verification

Flexibility in crediting periods and the life span of the project is allowed for the reasons described in the introduction to TRS SOC V2.0. A comprehensive verification checklist requires that the verifier confirm that the carbon project developer accurately represents conditions during favorable and unfavorable years (e.g., “normal precipitation and growing conditions as compared to drought years, etc.) with a robust and defensible record of the conditions, the activities during each year and measurement data each year it is collected. The verification process ensures that complete and accurate land use/land management records documentation, data and computations, and representations on credit yields (carbon accounting) are accurate, robust, and defensible. During each crediting event, buffer pool requirements, and the computation of credit yield during each true-up and a discounting adjustment, with verification also requiring conservative approvals, is required so that neither overrepresentation nor selling of credits occurs.

Verification of a Carbon Credit Project under the TRS SOC V2.0 is performed by pre-approved, third-party verifiers utilizing the guidance and checklists in Appendix 1.0 *Verification Guidance and Checklists* which include technical, management practice, and procedural evaluation of compliance with the TRS SOC V2.0 requirements. Any Verifier with sufficient knowledge and experience to ensure technical review and verification of projects under TRS SOC V2.0 must submit a Verifier Application with Nature’s Registry. See [Appendix 2](#VVB_prequal) for qualification requirements.

For Project Proponents executing the optional Task 3, annual recertification (i.e. verification of SOC changes in years between T0 and T1), utilizing the guidance and checklists in Appendix 1.0 *Verification Guidance and Checklists,* shall include a review of monitoring/proof of activities and any sample handling or SOC results that might have been received in this interim period. Examples of such documentation may include:

1. Farm records from USDA and NRCS showing acreages and confirming practices. We acknowledge these will only be obtainable to a carbon project developer with a release from the land steward. Consequently, these records will be considered private and confidential, to respect private land stewards’ rights.
2. Independent on-the-ground practice confirmations.
3. Independent remote sensing practice confirmations.
4. Maps, acreages, and written explanations of any deviations from a Project Plan including soil amendments, compost, etc.
5. Financial, meteorological, marketplace, personal explanation of deviations from a Project Plan.
6. Land Steward affidavit of continuation in the Project and compliance with Best Practice principles for regenerative land stewardship as defined by literature and agreed upon by the Project Proponent and Land Steward.

## Registration

After a project has been verified, a Project Proponent may request registration and credit issuance by submitting relevant documents to Nature’s Registry. The Registry will conduct a completeness review of the documents and an assessment of conformance of the program rules checklist. Once compliance is confirmed, the Registry will upload the documents to the public registry and issue Verified Carbon Credits (VCCs \*See definition) into the Project Proponent’s account. The public registry will make available to the public a summary of each project generating a credit issuance. Private landowner records, confidential data, contracts, and the reports that include these types of records will not become publicly available through the Registry. These records, however, will be available for internal and external auditors for the explicit purpose of quality assurance and control, and other auditor functions.

**Project Registration Process---** This process flow diagram illustrates the primary steps associated with project registration through registry functions.

Registry performs completeness and conformance review and VCC issuance

Registry reviews VCC records, performs automated checks and serializes VCC’s

Project Proponent submits project documents to Registry

**Document Includes:**

Completed Project Plan

Verification Report

Verification Checklist

Other, as required

The Registry invoices project proponent for VCC’s issuance levy

The Project Proponent pays VCC Issuance levy

a

The Registry deposits VCC’s into Project Proponent Account

Registry automates updating of ledger credit retirement, and all documentation records for ease of internal and external audit.

**Citations**

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USDA, <http://www.srs.fs.usda.gov>: 2021, see chapter Ngatia, L. M., D. Moriasi, J.M. Gracela, R. Fu, C.S. Gardener, R.W. Taylor Land use change affects soil organic carbon: an indicator of soil health. DOI: <http://dx.doi.org/105772/intehopen.95764>

USDA 2014 Quantifying greenhouse gas fluxes in agriculture and forestry: methods for entity-scale inventory. 8-57 pps. USDA Technical Bulletin 1939. https://www.usda.gov/sites/default/files/documents/USDATB1939\_07072014.pdf

Walter, H. 1983 Vegetation of the earth—and ecological systems of the geo-biosphere. Third edition, 318 pps. Springer-Verlag. New York.

Whittaker, R.H. 1975 Communities, and ecosystems. 385 pps. Macmillan, NY. ISBN-10-0024273902

# Appendix 1.0 Verification Guidance and Checklists

This guide provides instructions for the verification of carbon projects for Project Proponents and Verifiers to follow. The guide and checklist are to be followed by verifiers to efficiently conduct and document their verification process. In short, verification is intended to be a streamlined, rapid, and defensible process that:

1. Allows Verifiers, Project Proponents, approving bodies, and credit purchasers to understand projects, representations, and claims by the Project Proponents.
2. Provides a clear decision pathway for all parties to understand conclusions.
3. Provides a structure for efficient internal and external auditing of projects, programs, and accounts.

The verification process conclusions can be approvals and concurrence with the claims and representations by a Project Proponent. If the Project Proponent has provided an incomplete application, the verifier may request more information, clarifications, or the recognition of a fundamental problem that would not support a determination about application completeness, or support the claims and representations suggested by the Project Proponent. This verification process is intended to create a clear record to support resubmittal and completion of a review, and to encourage clear, open, and transparent communications by the Verifier, and others involved. Completeness requires proof of contract between the carbon project developer and the land steward(s) in each carbon project.

Fundamental to TRS SOC V2.0 and its verification process, must be the recognition that the proof is always in comparing forward assessments for optional interim crediting with actual baseline (T0) and follow-up measurements (T1, T2, etc.). TRS SOC V2.0 can use modeled or literature review projections early, but only measured performance is used for truing the actual credit yield by a Project. This means that representations in a project plan document only have material value when the baseline and subsequent follow-up measurements document performance.

This verification guidance is focused on using a checklist process. TRS SOC V2.0 Checklist Templates streamline the review process to ensure that all procedures are evaluated, and all TRS SOC requirements are met for each year (T0, T1, etc. and, if applying for interim credits, the years between T0, T1, etc.).

Using TRS SOC V2.0 Verification Report Template, the Verifier is expected to generate a report that summarizes whether the claims and representations suggested by the Project Proponent are certifiable to accompany the TRS SOC V2.0 Checklist Templates. If an application is deemed incomplete or if the checklist items do not meet the test of sufficiency, a Verifier should provide a follow-up attachment of no more than one-page in length that identifies deficiencies, discrepancies, and additional information needs.

It is the intention of The Regenerative Standard to maintain a vigilance to ensure verifiers and verification is completely independent of carbon project developers through execution of conflict of interest affidavits, and by updating disclosures, prequalification submittal applications, and also through external and internal audits. The open access requirements of The Regenerative Standard, data submittal requirements, including laboratory quality assurance and quality control execution programs, and the carbon program developer split samples and blind sampling submittal requirements ensure contribute to ensure quality, authenticity, and accuracy. The independent organization, agency, and standardized checklist of procedures of the Nature’s Registry provides yet another control over quality, accuracy, and robustness over the program.

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# Appendix 2.0 Validation and Verification Body (VVB) Prequalification

Validation and Verification Bodies (VVB’s) must be prequalified. Only qualified professionals/organizations who meet and demonstrate bonified educational and on-the-job field experience as verification and validation service providers for soil carbon crediting projects will be considered to be a qualified VVB by Nature’s Registry-the only registry currently issuing credits under The Regenerative Standard SOC V1.1, V1.2 and V2.0.

VVB’s are also required to submit proof of liability insurance (min $1M/instance) and, once engaged on a project, provide a copy of the service contract with the carbon project developer registering the project on Nature’s Registry.

**VVB Service Provider Requirements**

Projects intending to issue credits through Nature’s Registry require independent, third-party validation and verification by a prequalified VVB. This VVB provides independent verification and validation services to project developers confirming that the developer has accurately adhered to one of the registry protocols.

The VVB must represent and warrant the accuracy of the validation and verification process and reporting and provide true, accurate, and complete verification reports that have been independently arrived at by the VVB, as of the date of their signed attestation on a verification report.

There is no reciprocity for VVBs approved by other standards or registries at this time is granted without a service provider have received authorized prequalification to provide services for soil carbon crediting projects registered with The Regenerative Standard and Nature’s Registry.

Verification and validation service providers must sign a conflict of interest attestation guaranteeing there to be no financial interest in the project. A standard COI form must be signed by service providers and carbon project developers that acknowledges that service providers have not helped design, measurement or reporting, or project design document development, and have no influence on a carbon developers project or subsequent involvement and is only providing objective scientific peer review process, and a summary of findings services.

1. **Final Accreditation Requirement for Verification, Validation Service Providers:**

Within a period of 1 year of having completed the first verification or validation services under The Regenerative Standard or Nature Registry, a service provider must provide an additional proof of accreditation by: American National Standards Institute (ANSI), or International Accreditation Forum (IAF). This is in addition to the mandatory eligibility requirements of meeting professional, technical educational and experience requirements above, or an equivalent recognized accreditation, certification, and history.

# Appendix 3.0 Guidance on Potential Emerging Technologies Being Tested to Monitor and Measure Grazing Land Use Changes, and SOC Stocks

Projects may use emerging technologies to determine SOC content if sufficient scientific progress has been achieved in calibrating and validating measurement, and uncertainty is well-documented. This appendix summarizes a non-exhaustive list of potential emerging technologies (with a focus on remote sensing) to for example, monitor livestock grazing activities, explore the creation of proxy indicators that may be predictive of soil organic carbon changes. Any emerging technologies must be tested against reliable standard practices to ensure their robustness and reliability. This list of technologies may be updated to newer versions of the TRS SOC.

The applicability of a selected technology to measure SOC in a project must be demonstrated in several peer-reviewed scientific articles. Project Proponents should provide evidence of the ability of any emerging technologies to predict SOC content with sufficient accuracy through the development and application of adequate calibration with data obtained from classical laboratory methods, such as dry combustion. The site characteristics for the underlying calibration must match the project site conditions, including a range of SOC stocks, soil types, land use, etc. While the calibration requirements will vary by technology, as will the input data (e.g. Eddy covariance measurements calibration does not have to standardize for soil type) the use of emerging technologies for measurement must meet the standards for the calibration of each technology used by a project proponent. While projects may use the services of companies measuring SOC, the specificities of the applied measurement technology, including calibration methods, must be made available for review by a VVB. They must not have restricted access to intellectual property rights.

Table A.2 below presents potential emerging proximal sensing technologies that research and publications have deemed promising for streamlining SOC measurement. Although proximal sensing techniques may not be as precise per individual measurement compared to conventional analytical laboratory methods, e.g., dry combustion, proximal sensing may be more cost-efficient and provide a better balance between accuracy and cost. Hence, although each individual measurement may be less accurate, many more measurements can be made across time and space than would be feasible with conventional methods, enabling an overall estimate of carbon stock that is of similar or better accuracy than lower-density sampling that is measured with conventional analytical laboratory methods. Since many more proximal devices may be used in a project than would be used if all samples were sent to a single lab, care must be taken to demonstrate device-to-device calibration and precision.

Project Proponents must provide details to the VVB on the criteria and considerations of the emerging SOC measurement technology as specified in Table A.2. Projects should maintain adherence to these criteria over time to ensure that measurement and re-measurement are conducted under the same conditions and are thus comparable. While the focus is on proximal sensing, the Regenerative Standard is tracking scientific publications that document the developments related to remote (e.g., satellite) sensing of variables affecting SOC stocks on land. This includes exploration of relationships between remote sensed variables (e.g. % bare soil, C3/C4 plant cover, soil moisture, etc) that may or may not closely correlate with SOC stocks. Future revisions to this appendix may include guidance on using remote sensing of surrogate variables that can be remotely measured for technology demonstrated as scientifically credible and reliably predictive of SOC stocks.

#### Table A.2 Criteria to evaluate the use of emerging technologies based on proximal sensing to monitor and measure livestock use of land and proxy indicators or measures parameters of relevance to SOC content. This tabulation does not endorse, approve, or suggest a method is appropriate at this time for the measurement of parameters or variables of relevance, nor direct SOC measurements.

|  |  |
| --- | --- |
| **Method** | **Criteria and considerations to ensure robustness and reliability** |
| GPS collared livestock, or Telephone tower interpolation of livestock grazing behavior | * Reliable 24/7 tracking to understand grazing intensity, rotation periods, animal mass: grazing relations. Collar technologies have become commercially available. Line of sight technology disruption occurs in dense vegetation or irregular topographic settings which needs to be overcome. |
| Satellite/Drone imaging and tracking of livestock grazing behavior | * Reliable 24/7 tracking to understand grazing intensity, rotation periods, animal mass: grazing relations. * Visual disruptions because of line of sight technology requirements needs to be overcome. |
| Inelastic neutron  scattering (INS) aka neutron-stimulated gamma-ray analysis or spectroscopy | * If carbonates are present (calcareous or limed soils), inorganic C must be separately accounted for. * Inorganic gamma scintillators (detectors based on the sodium iodide NaI (Tl), bismuth germinate BGO, and lanthanum bromide LaBr3(Ce)) are better suited due to their higher efficiency of registering gamma rays in the energy range up to 12 MeV. * Pulsed Fast/Thermal Neutron Analysis (PFTNA) is the most suitable for soil neutron-gamma analysis. It allows separating the gamma-ray spectrum due to INS reactions from the thermal neutron capture and the delay activation reaction spectra. * Locally adapted calibration procedures must be included in the project documentation for VVB review. |
| Laser-induced breakdown  spectroscopy (LIBS) | * Soil samples must be dried for at least 24h at 40°C. * If carbonates are present (calcareous or limed soils), samples must be acid-washed. * Soil samples must be milled for homogenization and particle size reduction to facilitate the evaporation and atomization process in the plasma. * Before analysis, soil material must be pressed to form a pellet with a flat surface. * When measuring directly in the field (in-situ), appropriate corrections to remove soil moisture and further matrix effects must be applied. * The configuration of the LIBS instrumental parameters should be optimized for each matrix. The laser pulse energy and the diameter of the laser beam (i.e., spot size) should be monitored simultaneously in the laser pulse fluence term (laser pulse energy per unit area, J cm 2) as well as delay time, laser repetition rate, etc. * Projects may rely on chemometric methods for signal analysis, spectral preprocessing, and subsequent data processing and interpretation, including reducing matrix effects. * A description of the locally adapted calibration procedures must be included in the project documentation for VVB review. Multiple linear regression has proven to be an effective calibration strategy to tackle interference in soil carbon analysis. Further "non-traditional calibration strategies" as described in Fernandes Andrade, Pereira-Filho and Amara Siriwardena, 2021 and Costa et al., 2020 may be applied, which explore the plasma physicochemical properties, the use of analyte emission lines/transition energies with different sensitivities, the accumulated signal intensities, and multiple standards to obtain a linear model or calibration curve. * Multiple laser shots per sample may improve the measurement results. |
| Mid-infrared (MIR) and visible near-infrared (Vis-NIR and NIR)  spectroscopy, including diffuse reflectance spectroscopy (DRS) and diffuse reflectance infrared Fourier transform (DRIFT) measurements | * For MIR and NIR, soil samples must be air or oven-dried, crushed or sieved to a size fraction smaller than 2 mm, avoiding preferential sieving. * When measuring directly in the field (in-situ), appropriate corrections to remove soil moisture and further matrix effects must be applied. * The applied spectrometer should have a spectral resolution of 10 nm or less across the visible and near-infrared range (between 400 and 2500 nm), and spectra should be recorded in this range at 1 nm intervals. * Measurement protocols should be used when available, such as the Standard Operating Procedures of the Soil-Plant Spectral Diagnostics Laboratory of World Agroforestry Centre (ICRAF) * Calibration through multivariate statistics or machine-learning algorithms has been performed using large spectral libraries, such as the African ICRAF-ISRIC Soil Spectra Library, the multispectral data collected in the European LUCAS topsoil database, the USDA NRCS (KSSL) National Soil Survey Center mid-infrared spectral library or the Australian soil visible near-infrared spectroscopic database described in (Viscarra Rossel and Webster, 2012), or new site-specific libraries developed with local soil samples (higher accuracy). Sub-setting or stratifying the dataset can provide better calibration results. See (England and Viscarra Rossel, 2018) and (Stevens et al., 2013) for further guidance on calibration techniques and spectroscopic model development and validation. * Calibration procedures must be included in the project documentation for VVB review. |

The following scientific publications provide more details and further guidance on the application of the above-listed technologies to measure SOC:

##### INS

Izaurralde, R. C. et al. (2013) ‘Evaluation of Three Field-Based Methods for Quantifying Soil Carbon’, PLOS ONE, 8(1), p. e55560. doi: 10.1371/journal.pone.0055560.

Kavetskiy, A. et al. (2017) ‘Neutron-Stimulated Gamma Ray Analysis of Soil’, in New Insights on Gamma Rays. Intech Open. Available at: https://www.intechopen.com/books/new-insights-on-gammarays/neutron-stimulated-gamma-ray-analysis-of-soil.

Yakubova, G. et al. (2019) ‘Application of Neutron-Gamma Analysis for Determining Compost C/N Ratio’, Compost Science & Utilization, 27(3), pp. 146–160. doi: 10.1080/1065657X.2019.1630339.

##### LIBS

Costa, V. C. et al. (2020) ‘Calibration Strategies Applied to Laser-Induced Breakdown Spectroscopy: A Critical Review of Advances and Challenges’, 31(12). doi: https://doi.org/10.21577/0103-5053.20200175.

Fernandes Andrade, D., Pereira-Filho, E. R. and Amara Siriwardena, D. (2021) ‘Current trends in laser induced breakdown spectroscopy: a tutorial review’, Applied Spectroscopy Reviews, 56(2), pp. 98–114. doi: 10.1080/05704928.2020.1739063.

Senesi, G. S. and Senesi, N. (2016) ‘Laser-induced breakdown spectroscopy (LIBS) to measure quantitatively soil carbon with emphasis on soil organic carbon. A review,’ Analytica Chimica Acta, 938, pp. 7–17. doi: 10.1016/j.aca.2016.07.039.

##### MIR and (Vis-)NIR, incl. DR and DRIFT spectroscopy

Barthès, B. G. and Chotte, J.-L. (2021) ‘Infrared spectroscopy approaches support soil organic carbon estimations to evaluate land degradation’, Land Degradation & Development, 32(1), pp. 310–322. doi: 10.1002/ldr.3718.

Dangal, Shree R.S., Jonathan Sanderman, Skye Wills, and Leonardo Ramirez-Lopez. 2019. "Accurate and Precise Prediction of Soil Properties from a Large Mid-Infrared Spectral Library" Soil Systems 3, no. 1: 11. https://doi.org/10.3390/soilsystems3010011

England, J. R. and Viscarra Rossel, R. A. (2018) ‘Proximal sensing for soil carbon accounting’, SOIL, 4(2), pp. 101–122. doi: 10.5194/soil-4-101-2018.

Ng, W., Minasny, B., Jones, E. and McBratney, A. (2022) ‘To spike or to localize? Strategies to improve the prediction of local soil properties using regional spectral library,’ Geoderma, 406, https://doi.org/10.1016/j.geoderma.2021.115501

Nocita, M. et al. (2015) ‘Chapter Four - Soil Spectroscopy: An Alternative to Wet Chemistry for Soil Monitoring’, in Sparks, D. L. (ed.) Advances in Agronomy. Academic Press, pp. 139–159. doi: 10.1016/bs.agron.2015.02.002.

Reeves, J. B. (2010) ‘Near- versus mid-infrared diffuse reflectance spectroscopy for soil analysis emphasizing carbon and laboratory versus on-site analysis: Where are we and what needs to be done?’, Geoderma, 158(1), pp. 3–14. doi: 10.1016/j.geoderma.2009.04.005.

Sanderman J, Savage K, Dangal SRS. Mid-infrared spectroscopy for prediction of soil health indicators in the United States. Soil Sci.Soc. Am. J. 2020;84:251–261.https://doi.org/10.1002/saj2.20009

Seybold, C.A., et al., ‘Application of Mid-Infrared Spectroscopy in Soil Survey,’ Soil Sci.Soc. Am. J. 2019; 83: 1746-1759. https://doi.org/10.2136/sssaj2019.06.0205

Stevens, A. et al. (2013) ‘Prediction of Soil Organic Carbon at the European Scale by Visible and Near InfraRed Reflectance Spectroscopy’, PLOS ONE, 8(6), p. e66409. doi: 10.1371/journal.pone.0066409.

Viscarra Rossel, R. A. et al. (2016) ‘A global spectral library to characterize the world’s soil’, EarthScience Reviews, 155, pp. 198–230. doi: 10.1016/j.earscirev.2016.01.012.

Viscarra Rossel, R. A. and Webster, R. (2012) ‘Predicting soil properties from the Australian soil visible– near-infrared spectroscopic database’, European Journal of Soil Science, 63(6), pp. 848–860. doi: 10.1111/j.1365-2389.2012.01495. x.

# Appendix 4.0 The Regenerative Standard SOC Methodologies

TRS-1

METHODS TO DETERMINE STRATIFICATION

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## Table of Contents

[1 SOURCES 2](#_Toc14892)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc14893)

[3 DEFINITIONS 2](#_Toc14894)

[4 APPLICABILITY CONDITIONS 2](#_Toc14895)

[5 PROCEDURES 2](#_Toc14896)

[6 PARAMETERS 10](#_Toc14897)

[7 REFERENCES AND OTHER INFORMATION 10](#_Toc14898)

# 1 SOURCES

None

# 2 SUMMARY DESCRIPTION OF THE MODULE

The module provides the methods to be used to divide the project area or other areas into discrete strata, based on the delineation of areas within which the value of a chosen variable *X* is reasonably homogenous. Depending on the nature of the variable, and the time span of interest, homogeneity may be stated in terms of current values of *X* only, or may include processes leading to changes in *X* over time.

# 3 DEFINITIONS

**Project Area:** The area or areas of land on which the project proponent will undertake the

project activities.

**Stratum (plural strata):** An area of land within which the value of a variable, and the processes leading to change in that variable, are relatively homogenous.

# 4 APPLICABILITY CONDITIONS

The module is applicable for use in any methodology or module referencing stratification for a variable *X* which varies across the project area, reference region or other relevant land base.

# 5 PROCEDURES

### Introduction

Stratification is the process of dividing an area up into strata, based on variations in a specific variable *X. X* is any variable whose value varies across the project area or another relevant area – for instance, *X* may be a variable such as soil texture, soil carbon density, or amount of woody biomass per unit area. Areas are often heterogeneous in terms of micro-climate, soil condition and vegetation cover and management history, leading to the requirement for stratification. Stratification can increase the accuracy of the measuring and monitoring in a cost-effective manner. Stratification of an area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit.

The project proponent should recognize that mistakes in stratification could lead to significant increases in the cost and complexity of preparing a project description, and/or undertaking sampling and monitoring. At the same time, over-stratification (breaking an area into too many strata based on very small differences in the value of the variable) could equally lead to increases in cost and project complexity. In general, while stratification usually draws on quantitative data, ultimately most stratification is based to some degree on qualitative and subjective judgments. For this reason, the project proponent must document the rationale for such judgments at each step of the process.

Stratification will often be undertaken both before and after sampling, with the first stratification (“prestratification”) serving to increase the efficiency and effectiveness of the field sampling. After the sampling is complete, the project proponent can choose to refine the stratification using the results from the sampling, providing a final stratification.

The required steps of stratification are as follows:

### Step 1: Identification of the type of stratification variable *X*

**Goal**:Toidentify the type of stratification to be undertaken based on whether or not subsequent sampling will be required to determine values of *X* across the project area.

**Output**:Identification of the type of stratification to be undertaken, allowing the determination of the stratification methods to be used.

**Method**:Classify the type of variable for which stratification is being undertaken. Three types of variables can occur:

1. Variables for which the distribution of the variable across the areais known. For instance, existing surveys or remote sensing interpretation may have already quantified the variation in the population of trees across the area.
2. Variables for which stratification has previously been carried out within the area, but where changes in stratification are believed to have occurred, or are projected to occur, based on history or planning.
3. Variables for which the distribution of the variable across the area is not known. For instance there may be existing soil mapping, but the distribution of soil carbon across the site may not be known.

### Step 2: Identification of the time span of the stratification, and the variation through time of the variable *X*

**Goal:** To identify the correct temporal context for the stratification of *X.*

**Output:** A clear definition of the temporal period of interest for *X.*

**Method:** Stratification may be purely for analysis of current conditions, or may also be designed to be applicable throughout a longer period of time, during which changes to the variable *X* may occur. The types of time spans which can occur are:

1. Single point in time – stratification is to be used for the analysis of data from a single point in time. Therefore, analysis of processes leading to changes in *X* need not be taken into consideration.
2. Historic time sequence – stratification is to be used for the analysis of a historic time sequence of data regarding the variable *X*. If so, stratification must take into account an analysis of the differences in processes leading to change in *X* at different locations, rather than the status at any given time.
3. Future processes – stratification is aimed at enhancing the feasibility or accuracy of projections of future conditions, and thus considers both current conditions, and projected changes in the dynamics of the processes influencing *X*.

Identify which one or more of these time spans *X* falls into. In cases where *X* falls into more than one, methods applicable to each of the time spans must be used, and it may be beneficial to stratify separately for each of the time span types.

### Step 3: Selection of a stratification method

**Goal:** To identify the series of steps required to stratify for the variable *X.*

**Output:** Sequence of tasks to be undertaken to complete the stratification process.

**Method:** Select the series of steps to be undertaken to complete the stratification, based on the type and time span of the stratification for the variable X, as follows:

1. If the variable is of type 1 (the distribution of the variable across the area is known), and the time span of the stratification is either for a single point in time or for the variable over a historic period, complete the following sequence of steps:
   * Step 5: Pre-stratification
   * Step 7: Post-stratification
2. If the variable is of type 1 (the distribution of the variable across the area is known), but the stratification is to be undertaken for projection of future processes and states, complete the following sequence of steps:
   * Step 4: Identification of key factors
   * Step 5: Pre-stratification
   * Step 7: Post-stratification
3. If the variable is of type 2 (stratification has already been carried out, but conditions are thought to have changed), and the stratification is being undertaken for any temporal period, complete the following step:
   * Step 8: Re-stratification
4. If the variable is of type 3 (the distribution of the variable across the area is not known), and the stratification is being undertaken for any temporal period, complete the following sequence of steps:
   * Step 4: Identification of key factors
   * Step 5: Pre-stratification
   * Step 6: Qualitative truthing of stratification during sampling
   * Step 7: Post-stratification

### Step 4: Identification of key factors influencing the variable *X*

**Goal:** To develop an understanding, based on available information, of the factors and processes which determine the value of *X* at a given location, and the change in *X* through time.

**Output**: A list of key factors influencing the variable *X*, identifying for each factor:

* The name of the factor
* The nature of the effect of that factor on *X*
* A relative ranking of the importance of that factor, compared with other identified factors

**Method:** Identify, for the variable *X*, the key factors. For any variable *X*, there will be a number of key factors within the area, either currently or in the future which tend to cause change in the variable, and where the amount of change caused by that factor is expected to vary across the area. For instance, if *X* is tree density, key factors might include fire frequency, seed distribution, seedling survival. In cases where management has or is expected to influence *X*, management activities may also be included. For instance, if *X* is tree populations, plans to clear the trees from a portion of the area would be key stratification criteria.

For the purposes of stratification, identification of a key factor influencing *X* needs to be specific enough to allow different parts of the area to be distinguished depending on the degree of influence of the factor. However, this identification is not intended to allow quantitative projection of the future magnitude of effect on *X*. Thus for instance, knowing that different fire regimes are likely to lead to different tree populations is sufficiently specific, without being able to predict the future population dynamics of the trees under the different fire regimes. The intention of identifying key factors is to identify influences, not effects.

### Step 5: Pre-stratification

In cases where the data on which stratification will ultimately be based is not yet fully known, prestratification must be used to guide the data collection process.

**Goal:** Based on existing information and, if required, low intensity sampling, to divide the areainto relatively homogenous sub-areas based on variation in the variable *X*. The pre-stratification will be used to guide the more intensive sampling process.

**Output:** A series of outputs to facilitate stratification:

* A map showing the areadivided into discrete sub-areas based on variation in the current or historic values of the variable *X*, or the processes influencing *X*.
* A stratum definition for each stratum, giving the expected characteristics defining the stratum.
* A key factors definition for each stratum, identifying the key factors which are believed to be causing this stratum to be different from others. **Method:**

### Step 5a: Collection of information

Local information on key factors identified in Step 4 must be collected, such as:

* Local site classification maps and/or tables.
* The most updated land use/cover maps, satellite images and/or aerial photography.
* Soil types, parent rocks and preferably soil maps.
* Landform information and/or maps.
* Ecosystem maps.
* Fire regime maps or descriptions.
* Historical records of management.
* Management plans.
* Other information relevant to key factors identified above.

Data sources may include archives, records, statistics, study reports and publications of national, regional or local governments, institutes and/or agencies, literature and local knowledge.

For each data source collected assess the following:

* When was the work to derive the information undertaken?
* What specific work was undertaken to derive the data? For instance, if the data source is a soil map, was the map derived from actual sampling carried out within the area, or from extrapolation based on samples collected elsewhere?
* To what standards were the data collection and collation carried out? For instance, soil samples may have been analyzed in a lab, or may have been classified based on field texturing.

Based on these assessments, determine the overall quality of the data. This is particularly critical where the intention is to use existing data on the value of the variable as the majority of the basis for stratification.

Even where the data is of high quality, it is generally recommended that some truthing of the data, based on field reconnaissance, remote sensing data or other primary sources be undertaken to confirm the accuracy of the data.

### Step 5b: Preliminary stratification

The preliminary stratification must be conducted in a hierarchical order that depends on the significance of key factors on variations in *X*, or the differences in the key factors across the project area. The hierarchy of the key factors must be determined based on the degree of influence that each factor has on the value of the variable.

In many cases it may be difficult to determine which factor has the most influence on the value of *X*. For instance, soil carbon may be influenced by soil texture, biotic community and management, and it may not be clear which of these is the most important. In such cases, it is recommended that the factor which is least changeable be designated the highest level factor. In the example given, soil texture is likely the least changeable, and would therefore be the highest level factor, while biotic community might be second, and management might be third. The project proponent must document the reasons for their choice and ranking of factors.

The factor with the most influence must be the first factor considered, then the factor with the next most influence, and so on. At each level in the hierarchy, stratification must be conducted within the strata already determined based on higher level factors. For example, if climatic differences across the areaare the factor with the highest influence on the value of *X*, the stratification process must begin with stratification according to difference of the climate. If the second most important factor is soil type, then each stratum determined based on climatic differences must be further stratified based on differences of soil type.

Preliminary stratification is often most easily carried out on a Geographical Information System (GIS) platform, where information, maps collected, and field data can be overlaid. Whether or not the preliminary stratification is carried out using a GIS system, the project proponent must document the steps taken during the stratification process, and the reasons for each decision made.

### Step 5c: Supplementary sampling survey

Where existing information leaves doubt as to the homogeneity within or differences between preliminary strata, the project proponent should carry out a supplementary sampling survey to allow estimation of the value of *X* in each preliminary stratum. For example, the following characteristics can be surveyed to allow estimation of the value *X* within the preliminary stratum:

* Vegetation cover can be assessed by measuring randomly selected plots, using the plot methodology contained in module *TRS-2 Methods to Project of Future Conditions*.
* Site and soil factors can be assessed based on soil type, soil texture, slope gradient, intensity of soil erosion, and shallow ground water level, and sampling soils for soil organic and inorganic matter determination.
* Human intervention such as prescribed burning, logging, grazing, fuel collecting and plant collection can be assessed, by background research or local interviews.

The survey must use the methods given for sampling the variable in question in this methodology. Since the goal of this sampling is more qualitative than quantitative, sampling at this stage need not meet any specific standards for statistical variance.

### Step 5d: Strata homogeneity check

If pre-sampling was conducted, a further stratification must be completed based on supplementary information collected from Step 5c above, by checking whether or not each preliminary stratum is sufficiently homogenous, or whether the difference among preliminary strata is significant with regard to the variable *X*. The degree of homogeneity may vary from project to project and may be assessed based on stratum size in the context of the project, the degree of natural variability and the significance of the variability to the project and baseline scenarios. A stratum within which there is a significant variation in the value of the variable *X* must be considered for subdivision. On the other hand, two or more strata with similar features can be merged into one stratum. At the end of this step, strata should differ significantly from each other in terms of either current value or projected future values of *X*. For example, sites with different soil textures would usually form separate strata. Sites with a more intensive management (for instance tilled agriculture versus range) might also be a separate stratum. On the other hand, site and soil factors may not warrant a separate stratum as long as all lands have a similar trajectory with regard to future values of *X*.

### Step 5e: Pre-stratification map

A pre-stratification map, stratum definitions, and key factors definitions must be created, as follows:

* For the total area being stratified, prepare a pre-stratification map, preferably using a GIS (documenting “where is it different?”).
* For each stratum, document the unique characteristics which are believed to make this stratum different from all the others (documenting “what is different?”).
* For each stratum, document the specific processes which are believed to make this stratum different (documenting “why is it different?).

### Step 6: Qualitative truthing of stratification during sampling

**Goal:** To estimate the accuracy of the stratification through qualitative review of the stratification during field work.

**Output:** Sketch revision of the stratification maps, and draft revisions of the strata definitions and the key factors for each stratum, based on a qualitative review.

**Method:** In cases where stratification is part of a process including ground sampling, stratum types and boundaries established during the pre-stratification phase must be checked in the field during sampling. While the sampling itself will provide quantitative data which must be used during the post-stratification in Step 7, qualitative data must also be gathered during the sampling phase, and reviewed on an ongoing basis against the pre-stratification. Notes on observations, giving the location of the observation and what was observed, must be documented. Best practices for qualitative truthing include :

1. Line intersect notes. While establishing plots or other sampling points, and during other work during the sampling phase, the routes traveled between plots and other points should be tracked, and compared at that time with the proposed stratification. Notes on observations, giving the location of the observation and what was observed, must be taken. Field workers should observe and investigate the following questions:
   * Is there an observable difference in the field at the location proposed for the stratum boundary, in terms of the variable *X*, or factors which are believed to influence the variable *X*?
   * Does this observable difference instead, or additionally, occur at other places, which might serve to refine the stratum boundary?
   * Do the proposed strata appear different in the ways predicted during the pre-stratification, or are there in fact strata which could be amalgamated?
   * Does a proposed stratum appear to contain two or more different distinct subtypes, in terms of the variable *X*, which might justify creation of further strata?
2. Sketch mapping. Based on the line intersect notes, sketch mapping reflecting the observations made in the field should be prepared, noting any possible changes in stratification boundaries or strata definitions.
3. Stratum redefinition. Based on the field observations, proposed changes to the stratum definitions should be documented, including amalgamation or splitting of strata.
4. Stratum process redefinition. Based on the field observations, proposed changes to the documentation of the processes which are believed to be driving the status of the variable *X* within each stratum should be documented.

### Step 7: Post-stratification

**Goal:** Finalization of the stratum definitions and stratum mapping.

**Output:** Documented stratum definitions, and final stratum maps.

**Method:** After the intensive sampling phase, undertaken using the techniques in the relevant modules, or based on the known distribution of the variable, post stratification must be undertaken to determine or refine the stratification based on the quantitative and qualitative data collected or already existing. Using the data collected in the field or the existing data:

* Refine the stratum definitions, including subdivision or amalgamation of strata where necessary.
* Refine the stratum mapping to produce final stratum maps. This remapping must be based both on any changes indicated by the data collected, as well as on the sketch mapping undertaken in Step 6.

Refining of both stratum definitions and stratum maps should strongly consider both the pre-stratification, if undertaken, and the qualitative data gathered in Step 6, or the existing data if the distribution of the variable is known. During the post-stratification phase there is often a tendency to trust the quantitative plot data despite qualitative or other evidence which suggests that the quantitative data may not be representative. During post-stratification, the limits of statistical reliability, particularly of single plots as an indicator of stratum boundaries, should be acknowledged, and considerable weight should be given to the qualitative observations of experienced field people.

Note that if the stratification is being determined for use in projecting future conditions, the key factors and processes influencing the variable, determined in Step 4, must be considered in determining the stratification. A stratum must not only be similar in the value of the variable *X* at the present, but the processes and key factors must also be similar, such that the future values of the variable within the stratum are expected to remain similar. If this is not the case, consideration must be given to breaking the stratum into two or more strata, based on groupings of key factors and processes driving the future value of the variable *X*.

### Step 8: Re-stratification

**Goal:** To correct stratification to reflect changes in conditions.

**Output:** Documented revised stratum definitions, and stratum maps.

**Method:** Through time, changes in conditions or processes can lead to changes in stratification. This will be particularly the case when undertaking work on Task 4 of *TRS-3 Soil Carbon Quantification Methodology*. Implementation of treatments may ultimately take place using different methods, in different areas, and at different time than was forecast in the project plan. Also, natural events may substantially change the nature and processes of areas within or across previously established strata.

The project proponent must routinely re-examine project area conditions to determine where events or actions may have occurred that could cause changes in stratification. The project proponent must conduct such a review prior to each monitoring event. Where such events or actions have occurred, the project proponent must repeat any or all of Steps 4 through 7, as required, to determine if, when and where, stratum boundary revisions are required.

Where re-stratification is conducted, changes in permanent sample plots are required under the following circumstances:

* Where re-stratification results in the subdivision of existing strata, the project proponent must assess whether additional sample plots need to be added to meet statistical requirements for sampling of the variable in question. Where re-stratification results in combining two or more strata, permanent sample plots must not be dropped even if the total number of plots in the new stratum exceeds the number required to achieve required levels of statistical accuracy.
* Where re-stratification results in a permanent sample plot lying on the boundary between two strata, the plot must be dropped.

# 6 PARAMETERS

None

# 7 REFERENCES AND OTHER INFORMATION

None

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-2

METHODS TO PROJECT FUTURE CONDITIONS

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 2](#_Toc48467)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc48468)

[3 DEFINITIONS 2](#_Toc48469)

[4 APPLICABILITY CONDITIONS 3](#_Toc48470)

[5 PROCEDURES 3](#_Toc48471)

[6 PARAMETERS 31](#_Toc48472)

[7 REFERENCES AND OTHER INFORMATION 31](#_Toc48473)

# 1 SOURCES

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

# 2 SUMMARY DESCRIPTION OF THE MODULE

Preparation of ex-ante projections of GHG pools and emissions under the baseline and project scenarios requires making informed estimates of future values of a wide range of variables. Some examples of the sorts of variables that might need to be projected include:

* Specific pools or emissions. For example, it might be necessary to estimate the future amount of carbon stored in the soil pool under the baseline scenario, using a soil carbon model.
* Market factors which influence pools or emissions. For example, it might be necessary to project future demand for a particular commodity when assessing the rate at which production of that commodity would grow within the project area.
* Human and cultural factors which influence pools or emissions. For example, it might be necessary to project what a particular farmer would do on a property in the future, based on that farmer’s needs and desires.
* Biological and related factors which influence pools or emissions. For instance, it might be necessary to project the impact that global warming-related weather changes will have on frequency of fires in rangeland.

The module provides a step by step approach to assessing the key factors that drive change in the variable in question, and it provides a suite of methods and approaches for projecting future conditions, as well as decision criteria for choosing the correct method, for the variable in question.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Baseline:** | The total amount of carbon within the project area in absence of the project. |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project. |
| **Conservative:** | Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables. |
| **Controlled:** | Change in a variable is under the control of the project proponent. |
| **Ex-ante:** | Before the fact. Projection of values or conditions in the future. |
| **Ex-post:** | After the fact. Estimation of values or conditions in the present or past. |
| **Leakage Zone:** | Zone in which the leakage is expected to occur and therefore needs to be monitored. |
| **Location Specific:** | Variations in the value of a variable are tied to a specific location, and typically that the value of the variable changes across the landscape. |
| **Location Specific Approach:** | An approach to predicting the future value of a variable which takes account of changes across the landscape, and predicts different values of the variable in different places. |
| **Planned:** | Changes in the value of the variable are under the control of identified agents who are independent of the project proponent. | |
| **Process Specific:**    **Project Area:** | Variations in the value of the variable are associated with specific actions, ongoing events, or global conditions, rather than with specific locations.  The area or areas of land on which the project proponent will undertake the project activities. | |
| **Project Scenario:** | The actions and events which are expected to occur as a result of implementing the project. | |
| **Proxy:** | See *VCS Program Definitions.* | |
| **Reference Condition:** | A condition of the ecosystem which is believed to have existed at some time, and which reasonably approximates the intended condition which will exist if the project is successful. | |
| **Reference**  **Region/Area:** | An area of land outside of the project area, but which displays similar conditions to some or all of the area within the project area, and which can therefore be analyzed to understand processes which have or may occur within the project area. | |
| **Stratification:** | The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people. | |
| **Stratified Approach:** | Projection of future conditions based on the division of the area into strata, and the projection of a single value of the variable for each stratum at each time. | |
| **Systemic:** | A variable whose future value depends primarily on one or more causes not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems (economic, ecological, etc.) outside of local control. For instance, cattle grazing intensities in an area may go down if there is a large drop in the price of beef. | |
| **Value Class:** | A range of the value of a variable which will be treated as a single set, for the purposes of analysis. For instance, all areas with forest cover between 70% and 100% might be treated as a single value class, and analyzed on that basis. | |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

### Introduction

The moduleis designed to allow the projection of future values of a variable, *X*, which has been identified as having a significant influence on the future GHG impacts of emissions or changes in pools under the baseline or project scenario. This variable will fall into one of two types:

1. The variable is location specific. That is to say, the variable is associated with the land and varies across the landscape. For instance, carbon in living biomass and soil carbon are both location specific variables. Location specific variables can often be estimated and projected for a specific moment in time. For instance, the total biomass or the total soil carbon at a given moment in time on a given area can be estimated using sampling techniques.
2. The variable is process specific. Process specific variables are associated with specific actions, ongoing events, or global conditions, rather than with specific locations. For instance, emissions from power equipment are ongoing events, and therefore process specific. Process specific variables are often, although not always, estimated or projected for a time span. For instance, emissions from fuel use are typically estimated over a time span such as a year. Thus while one could estimate soil carbon in a given area at a point in time, typically one would estimate fuel use over a period of time.

Either of these types of variables can fall into one of 3 categories:

1. *Controlled*. The future value of the variable will primarily be a result of actions under the control of the project proponent. For instance, the project proponent intends to reduce the cattle grazing intensity by 25% on land they control.
2. *Planned*. The future value of the variable will primarily be the result of planned or projected actions by one or a few parties acting independently of the project proponent. For instance, farmers in the area have stated that they plan to reduce the cattle grazing intensity, but the project proponent cannot force this to happen.
3. *Systemic*. The future value of the variable depends primarily on one or more conditions whose future value is not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems outside of local control. For instance, cattle grazing intensities in the area may go down if there is a large drop in the price of beef.

These combinations of variable type and category gives rise to four different classes of variables:

1. Controlled variable, either location or process specific
2. Planned variable, either location or process specific
3. Systemic variable, location specific
4. Systemic variable, process specific

In all cases, Steps 1 through 5 must be used to determine the class of variable being projected. Classes will then require different sequences of steps to project the future conditions of the variable, as follows:

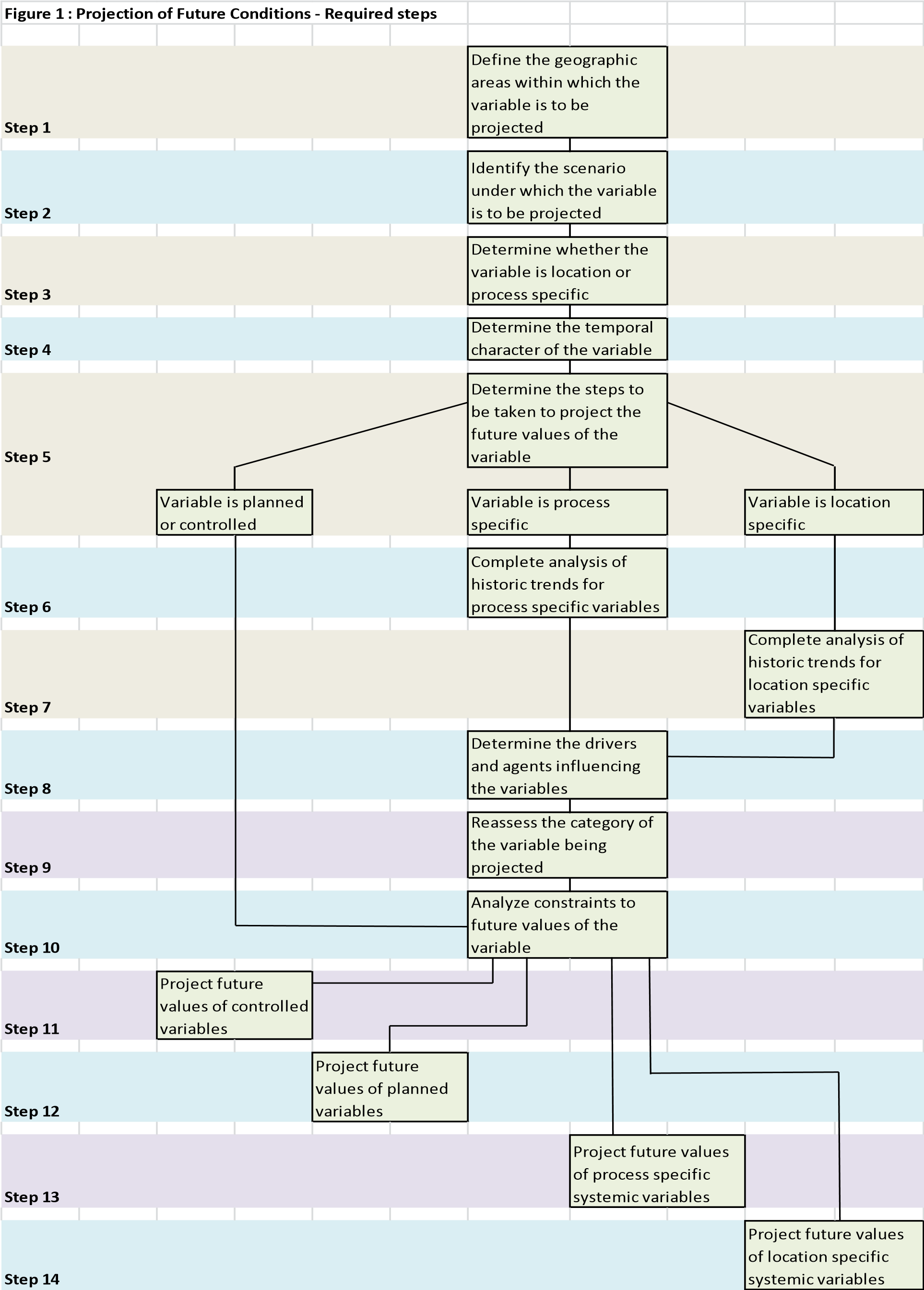
1. Controlled variable, either location or process specific
   * Step 10 to determine the limits to the possible values of the variable
   * Step 11 to verify the planned actions of the project proponent
2. Planned variable, either location or process specific
   * Step 10 to determine the limits to the possible values of the variable
   * Step 12 to verify the planned actions of the agents impacting the value of the variable
3. Systemic variable, location specific
   * Step 7 to determine the historic trends in the value of the variable
   * Step 8 to determine the agents, causes and drivers impacting the value of the variable
   * Step 9 to re-examine the category of the variable. It is possible that during this step variables will be found to be controlled or planned, even though they were initially assessed as

systemic. In that case, follow the sequence of steps for either controlled or planned variables. Step 10, to determine the limits to the possible values of the variable

* + Step 14 to project the future values of the variable

1. Systemic variable, process specific
   * Step 6 to determine the historic trends in the value of the variable
   * Step 8 to determine the agents, causes and drivers impacting the value of the variable
   * Step 9 to re-examine the category of the variable. It is possible that during this step variables will be found to be controlled or planned, even though they were initially assessed as systemic. In that case, follow the sequence of steps for either controlled or planned variables
   * Step 10 to determine the limits to the possible values of the variable
   * Step 13 to project the future values of the variable

The sequences of steps required are shown graphically in Figure 1 below:



### Step 1: Define the geographic area(s) within which the variable *X* is to be projected

**Goal**: Determine the geographic area(s) within which or for which changes in the variable *X* are to be determined, and map these areas to the standards required for mapping of the project area

**Methods and guidance**: Identify the area within which the variable will be projected. This may be a stratum, the project area, or the project area plus a reference region. Projection may also be required within a leakage zone if the leakage zone method is being used to determine leakage (Step 3 of module *TRS-14 Estimation of Emissions from Activity Shifting Leakage*).

In some cases, the projection of location specific variables may not occur over the whole project area, but on a stratum by stratum basis. Where this is the case, the defined areas will be the strata, and each stratum will be analyzed and projected separately. However, much of the work in projecting future conditions will be the same for all of the strata, and the analyses may be conducted in parallel, noting the differences between the strata.

### Step 2: Identify the scenario under which the variable *X* is to be projected

**Goal**: Determine whether the variable is to be projected under the baseline scenario or the project scenario, or both, and document the results

### Step 3: Determine the type and category of the variable being projected

**Goal**: Determine whether the variable is location specific or process specific, and whether the variable is controlled, planned or systemic, and document the reasoning and evidence for each of these determinations.

**Methods and guidance**: Determine whether the variable is location specific or process specific. Note that some variables can bear some characteristics of both types. For instance, cattle populations may vary across the landscape, but are typically determined by the rancher, based on their knowledge of the carrying capacity of the land as a whole, rather than specific portions of it. In this case, cattle populations would be a process specific variable, since the primary determinant of the variable is not the characteristics of a specific location, but the decisions of the rancher.

On the other hand, conversion of an area of land from forest to pasture by settlers will typically be location specific because, although the settlers are making the decision to clear, they will typically decide to clear the best land first – thus the primary determining factor in whether or not a specific area of land is cleared will be a characteristic of the location – in this case the quality of the land.

In general, if the percentage change of the variable in question under the scenario being examined occurs at different rates within the area, and this variability is significantly determined by a variability of the land within the area being examined, the variable is considered location specific.

If the percentage change of the variable in question under the scenario being examined occurs primarily as a result of decisions or processes which are not dependent on the characteristic of a specific location, the variable is process specific.

Either of these types of variables falls into one of three categories. Determine which category the variable falls into, based on the following guidance:

* *Controlled*. The future value of the variable is controlled if changes in the variable will primarily be a result of actions under the control of the project proponent. For instance, the project proponent intends to reduce the cattle grazing intensity by 25% on land they control.
* *Planned*. The future value of the variable is planned if changes in the variable will primarily be the result of planned or projected actions by one or a few parties acting independently of the project proponent. For instance, farmers in the area have stated that they plan to reduce the cattle grazing intensity, but the project proponent cannot force this to happen.
* *Systemic*. The future value of the variable is systemic if changes in the variable depend primarily on one or more conditions whose future value is not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems outside of local control. For instance, cattle grazing intensities in the area may go down if there is a large drop in the price of beef.

### Step 4: Temporal character of the variable

**Goal**: Determine the temporal character of the variable, and document the reasons for the determination.

**Methods and guidance**: The temporal character of the variable is defined by the time period over which the variable has existed and the reasons for it existing. Variables are:

* *Inherent.* The variable is an inherent characteristic of the area or the natural processes affecting the area, and therefore the variable existed without human intervention or existed as a result of human actions over a very long period of time in the past (for instance, traditional landscape burning by indigenous peoples).
* *Caused.* The variable is a characteristic which arose as a result of some specific human action at a known time, and therefore has a clear start (for instance, commencement of grazing of domestic sheep in an area).
* *Projected*. The variable is a characteristic which will arise as a result of projected human activities at some time in the future under the baseline scenario (for instance, humans caused deforestation in an area which currently has never been deforested).
* *Intended*. The variable is a characteristic which will arise as a result of the project activities under the project scenario (for instance, emissions from project activities).

If a variable is projected, and is also a systemic variable and location specific, reference areas should be found within which the characteristics and processes of change associated with the variable already exist. For instance, an area within which human caused deforestation is already occurring. If no such area can be identified, a modeled approach must be used to project the future values of the variable in Step 14.

### Step 5: Determination of the steps to be taken to project the future value of the variable

**Goal**: Based on the previous steps, determine and document the degree of certainty of the type, category and temporal character of the variable, and based on this determination lay out the series of steps which will be undertaken to project the future values of the variable.

**Methods and guidance**: In order to demonstrate a high degree of certainty in the determinations of the type, category and temporal character of the variable, the project proponent must be able to demonstrate and document that under current conditions the statement is true, and that anticipated future changes in conditions are unlikely to make it untrue. For instance, if the variable in question is cattle grazing densities on land owned and managed by the project proponent, it is true that at the current time the project proponent controls the amount of cattle grazing on that land. If it is also true that there is very low likelihood that the project proponent will surrender ownership or management of the land in the future, then it can be stated that with a high degree of certainty cattle grazing densities are a controlled variable.

Based on this determination, for the variable in question:

If there is a high degree of certainty that the future change in the variable under the scenario in question will be determined by the project proponent, or by agents under his or her control, the variable is controlled. Go to Steps 10 and 11. If not, then:

If there is a high degree of certainty that the future change in the variable under the scenario in question will be determined by a known group of agents independent of the project proponent, the variable is planned. Go to Steps 10 and 12. If not, then:

If the variable is process specific, go to Step 6. If the variable is location specific, go to Step 7.

Note that in some cases stratification of the project area may need to take these distinctions into account. For instance, if the project area consists of two pieces of land, including an area of land which may be homesteaded and converted in part to cropland by settlers who have not yet arrived, and an area of land owned by a single family, who plan to convert it into cropland, then the project area should be stratified with the first area being analyzed as systemic and location specific and the second area analyzed as planned.

### Step 6: Analysis of historic trends for process specific variables

**Goal**: Gather, document and analyze the available data on historic trends in the value of the process specific variable. Based on this work, produce a summary of the historic trends which indicates both the results of the analysis and any uncertainties resulting from data gaps or low quality data.

**Methods and guidance**: Initially, determine whether or not there is any historical occurrence of the variable in the analysis area. If the variable in question had no value prior to the current time, or currently has no value (for instance if the variable is project emissions from the use of power equipment, assessed at a time prior to the commencement of the project), skip this step and go to Step 13. If not:

Gather and document all available information on historic changes and values of process specific variables. Rate the reliability of the information, and note any information gaps which may exist.

Information should be drawn from any available documented sources. These may include:  Local, regional or national government mapping, statistics and records

* Land title records
* Published and unpublished research
* Local records contained in newspapers, NGO and business records
* Economic data

Where appropriate, information from oral sources should also be collected, as in many cases, information from oral sources may be the only available information, or may substantially increase the available body of information.

Based on the information gathered, determine and document the most likely historic trajectory of change in the variable over a period of at least 10 years. Assess and document the degree and causes of uncertainty associated with this work.

### Step 7: Analysis of historic trends for location specific variables[[3]](#footnote-5)

**Goal**: Analyze historic trends for location specific variables, using the appropriate methods given below. Document each of the steps taken, the data sources, methods of analysis, and degree and potential sources of uncertainty.

**Methods and Guidance**: For the purposes of Step 7, location specific variables are categorized into three types:

* *Assessable through remote sensing*. For instance, if the variable is forest cover, it can generally be directly assessed from remote sensing, both satellite, as well as aerial photography for periods prior to the availability of satellite based sensing.
* *Partly assessable through remote sensing using a proxy*. Some variables, such as soil carbon, are not directly assessable through remote sensing, however, in a given ecosystem, soil carbon may be reasonably correlated with vegetation cover types which are detectable through remote sensing.
* *Not assessable through remote sensing*. While many variables can be at least partly assessed using proxies and remote sensing, some variables may not be detectable using remote sensing. For instance, in some ecosystems soil texture may not produce vegetation or other changes detectable by remote sensing.

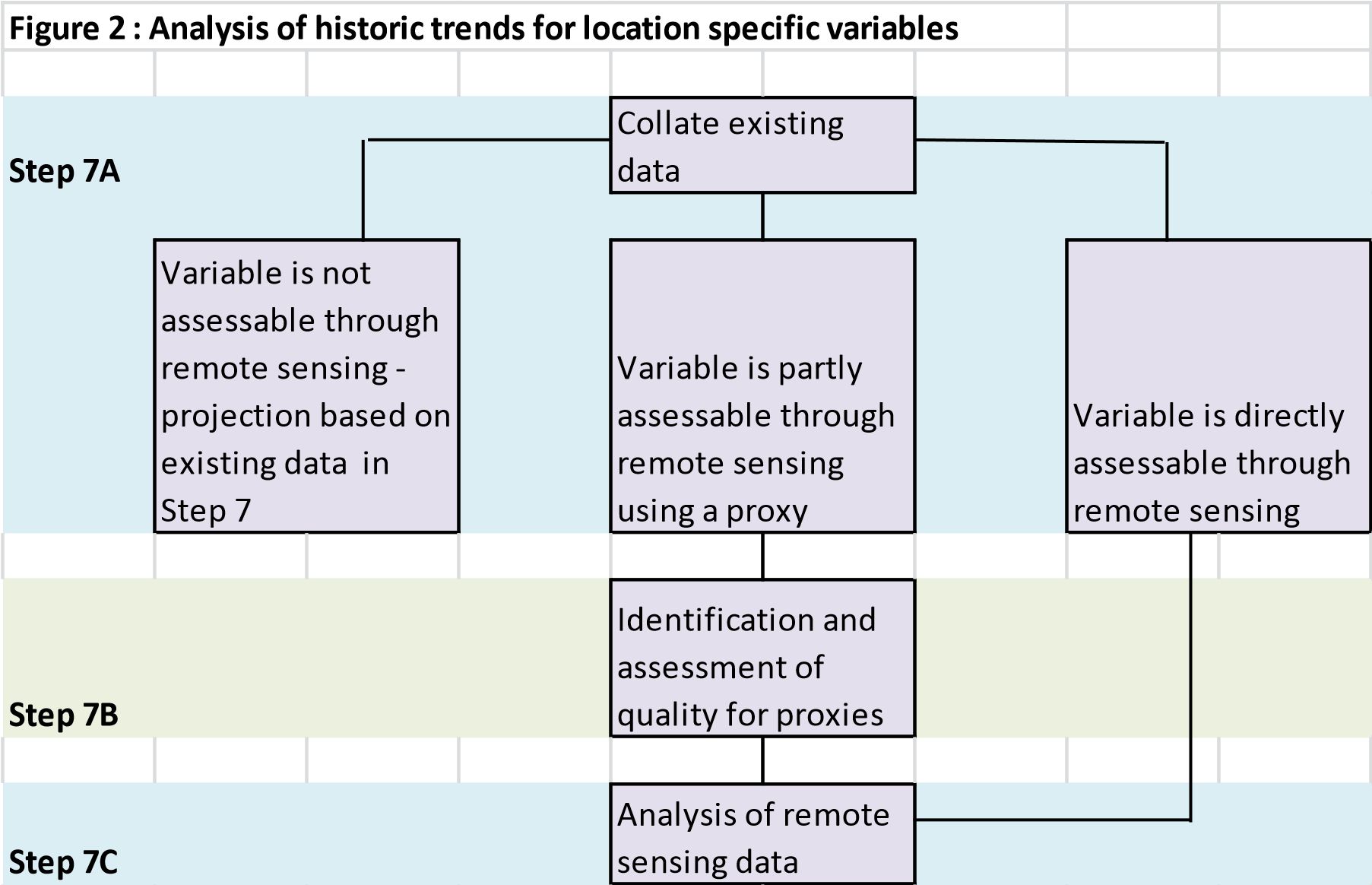
For each of the three types, a specific set of steps must be followed, as follows:

* Assessable through remote sensing – Steps 7a and 7c
* Partly assessable through remote sensing using a proxy - Steps 7a, 7b and 7c
* Not assessable through remote sensing – Step 7a

Where assessment through remote sensing is to be done, either directly or through a proxy, it should be done for both the project area and the reference region if projection is being undertaken as part of Task 2, the baseline. Assessing the wider area will give more information on trends in the value of the variable over time.

Where a leakage zone is being used to monitor leakage, the leakage zone must also be assessed during this phase.

The sub-steps in Step 7 are shown in Figure 2 below.



### Step 7a Collation of existing data

Collation and analysis of existing data must be undertaken as described for Step 6. Particular attention should be paid to existing spatially specific data such as maps, historic studies and ground level photography.

Note that if the variable in question is assessable or partly assessable through remote sensing, it is possible that existing work has already been done for the area to classify it for the variable in question, or the proxy variable being used. If this classification can be shown to have been of good quality, using consistent methods for multiple time points, it may be unnecessary to undertake further remote sensing interpretation. If such data exists for only one time point, and the methods used to produce the data are known, it may be possible to undertake assessment of other time points following the steps below using the same methods, and thus reduce the amount of remote sensing interpretation required.

It is also possible that high quality time series data derived from direct sampling and measurement of the variable in question exists for the area from other sources – for instance repeat soil surveys associated with management. If data of this type is available, it should form the primary source for determining the historic trends for the variables. In this case, depending on the degree of geographic coverage of the existing data, project proponents may optionally conduct the remote sensing analysis described in Step 7c below as a back-up to the existing data, or to extrapolate it to areas not covered by the existing data.

### Step 7b: Identification and assessment of quality for proxies

Proxies are features visible with remote sensing that provide indications of the status of features which are not visible with remote sensing. Proxies should be identified from one of the following two sources:

* Existing scientific literature on processes and relationships within landscapes, particularly landscapes with similar ecosystems and processes to the area being examined.
* Correlation between characteristics visible in current remote sensing images, and data on the status of the variable in question, drawn from field surveys undertaken to the standards laid out for field surveys in this methodology, or to similar standards.

Proxies identified from the scientific literature must be verified onsite using the second approach. Based on the correlation of field surveys and current remote sensing images, the project proponent must document:

* The nature of the characteristics detectable in the remote sensing images which correlate with differences in the state of the variable *X* on the ground.
* The apparent degree of correlation between the two, based on statistical analysis of the relationship.
* The theoretical basis for the proposed correlation. In other words, the project proponent must offer a reasonable explanation of why the correlation between the proxy and the variable in question exists.

### Step 7c: Analysis of remote sensing data

The goal of the analysis of remote sensing data is to produce a time series of assessments of the value and variation of the variable *X*, or a proxy, across the area. This data on historical values and geographic correlations of the variable will be used later in this module to assist in the projection of future values of the variable on a location specific basis.

In order to maximize the value of this step, the following process must be followed:

### Step 7c.1: Identification of the probable rate of change and historic period of change

Depending on the specific variable in question, the rates of change, and period over which the change has occurred, may vary substantially. The project proponent must determine and document the best information or estimates that they have available on:

* When the change from the reference condition began, if a reference condition exists for the variable. (See Step 8a below for a discussion of the reference condition.)
* How long the variable took to reach a state approximately like that currently existing, for a specific location.
* Whether the variable has now reached a relatively stable condition at any place within the area, or whether significant change is still occurring everywhere.

Based on this data, the project proponent must determine what the time period is over which they will need to analyze the value of the variable to be able to determine reasonably the rates and trajectory of change for a given location, and for the area as a whole. This period does not need to encompass the whole history of change in the variable, but should be sufficiently large to encompass a significant portion of the history of change. The time period may also be significantly constrained by the availability of remote sensing imagery, based on the work undertaken in 7c.2 below.

### Step 7c.2: Location of the available remote sensing resources

Identify the time span over which there are available remote sensing images. These could include satellite images and aerial photography. It is also possible in some cases that this could include ground-based photography where enough location identifiers are present to allow georeferencing of some features.

If the available resources will not adequately capture a meaningful proportion of the period of change defined in 7c.1 above, go to Step 8. Otherwise, select specific images which cover the time period. Ideally images will be relatively evenly spaced. A minimum of three images from different times (beginning and middle of the time period, and a current image) must be used if available. In many instances, using 4 images may be useful, allowing more scope for truthing of extrapolated rates and locations of change in the variable.

### Step 7c.3: Pre-processing

Pre-processing typically includes:

1. Geometric corrections to ensure that images in a time series correlate properly to each other and to other Geographical Information System (GIS) maps used in the analysis (i.e.

for post-classification stratification). The average location error between two images should be < 1 pixel, to allow utilization of automated change detection systems.

1. Cloud and shadow removal using additional sources of data (e.g. Radar, aerial photographs, field-surveys). In general images with more than 10% cloud cover within the area being analyzed should have cloud and shadow removal done, or should be discarded.[[4]](#footnote-6)
2. Radiometric correctionsmay be necessary (depending on the change-detection technique used) to ensure that similar objects have the same spectral response in multitemporal datasets.
3. Reduction of haze, as needed.

See Chapter 3 of the GOFC-GOLD sourcebook on RED (Brown *et al.,* 2007) or consult experts and literature for further guidance on pre-processing techniques.

Duly record all pre-processing steps for later reporting.

### Step 7c.4: Interpretation and classification

Two main categories of change detection exist and can be used (see IPCC 2006 GL AFOLU, Chapter 3A.2.4):

1. Post-classification change detection: Two maps are generated for two different time points and then compared to detect changes in the variable being examined. The techniques are straightforward but are also sensitive to inconsistencies in interpretation and classification of the value of the variable.
2. Pre-classification change detection: These are more sophisticated approaches to change detection. They also require more pre-processing of the data (i.e. radiometric corrections). The basic approach is to compare by statistical methods the spectral response of the ground using two data sets acquired at different dates to detect the locations where a change has occurred and then to allocate different patterns of spectral change to specific types of change in the variable. This approach is less sensitive to interpretation inconsistencies but the methods involved are less straightforward and require access to the original unclassified remotely sensed data.

As several methods are available to derive maps of changes in the variables from multi-temporal data sets, no specific method is recommended here. As general guidance:

* Automated classification methods are often preferred because the interpretation is more efficient and repeatable than a visual interpretation. However, automated classification should be carefully examined for potential systematic errors. If such errors are not correctable, manual classification may be required. Particular attention should be paid to possible errors caused by combinations of terrain and time of day causing differences in spectrum or brightness which are not correlated with any change on the ground.
* Independent interpretation of multi-temporal images should be avoided (but is not forbidden).
* Interpretation is usually more accurate when it focuses on change detection with interdependent assessment of two multi-temporal images together. A technique that may be effective is image segmentation followed by supervised object classification.
* Minimum mapping unit should be determined based on the resolution of the images.
* See Chapter 3 of the GOFC-GOLD sourcebook on RED (GOFC-GOLD, 2009)[[5]](#footnote-7) or consult experts and literature for further guidance on methods to analyze change in variables using remotely sensed data.
* Typically, remote sensing results should be stated in terms of value classes rather than values. For instance, if the variable being assessed is ground cover, cover classes should be defined. (For instance, 80% to 100% cover, 50% to 80% cover, etc.) The value classes defined should be classes which are expected to be reliably distinguished from the remote sensing.

Duly record all interpretation and classification steps for later reporting.

### Step 7c.5: Post-processing

Post-processing includes the use of non-spectral data to further assess differences in the variable across time and across the landscape. Post-classification stratification can be performed efficiently using GIS.

Current remote sensing technology may be unable to accurately discriminate certain changes in the variable. Where there is likely to be a wide variation in the value of the variable that has not been picked up from the remote sensing work, other data sources must be integrated into the GIS at this point, such as:

* Biophysical criteria (e.g. climate or ecological zone, soil and vegetation type, elevation, rainfall and aspect);
* Disturbance indicators (e.g. vicinity to roads and concession areas);

* Land management categories (e.g. protected forest and indigenous reserve); and/or,  Other criteria relevant to differences in the variable.

Duly record all post-processing steps for later reporting.

At the end of Step 7c.5, the following products must be prepared:

1. A map for each date analyzed, showing the estimated values of the variable across the area.
2. A change map, showing the change in the value or value class of the variable from each date to the next date analyzed for each point or area analyzed. Many projects will have some level of no-data areas because of cloud-cover. In this case, change rates must be calculated for each time step based only on areas that were not cloud-obscured in either date in question.
3. A change matrix for each change map. The matrix will be a table showing, for each classification of the variable on the first date, how many hectares were in that classification, what classifications those hectares fell into on the second date.

### Step 7c.6: Map accuracy assessment

Project proponents must demonstrate the accuracy of the maps through a verifiable accuracy assessment. The accuracy assessment should be demonstrated with the following procedure.

The accuracy assessment should be undertaken by comparing the value or value class of the variable as mapped with the actual value or value class of the variable as determined from other sources. This is most likely to be undertaken on the mapping of the current conditions, where ground based work can be undertaken to confirm the value of the variable. A number of sample points on the map and their corresponding correct classification (as determined by groundsurveys or interpretation of higher resolution data) should be assessed.

The minimum overall accuracy of the map assessed should be 90%. In other words, not less than 90% of the randomly selected sample points should be correctly classified. Furthermore, examination of the incorrectly classified sample points should not reveal a systematic error with an identifiable cause. For instance, if most of the points incorrectly classified as grassland were actually shrubland, and the error resulted from topographically caused changes in spectrum or luminosity, the classification work should be redone to correct for this systematic error.

Where the mapping shows a number of different value classes for the variable (for instance, 100% ground cover, 70% ground cover, etc.), the minimum classification accuracy for each of these value classes on the map should be 80%. If the classification of a class is lower than 80%, consider merging the class with other classes[[6]](#footnote-8); Thus for instance if ground cover is being classified and if the 100% cover and 70% cover classes are difficult to distinguish and often misclassified, consider combining the two categories. Again, in this case, where random checking shows systematic error with an identifiable cause, the work should be redone.

Both commission errors (false detection of a value or value class, such as “deforestation”) and omission errors (non-detection of actual value or value class, such as “deforestation”) should be estimated and reported.

The “goodness of fit” measure should include an assessment of the correct estimation of the quantity of change and an assessment of the correct location of change. To measure the degree to which a simulated map agrees with a reality map with respect to both location and quantity of pixels, Kappa-for-location and Kappa-for-quantity can be used, respectively (Pontius, 2000).

Where the assessment of map accuracy requires merging or eliminating value classes to achieve the required map accuracy, the definitions of the value classes must be adjusted accordingly. The final maps and the value class definitions must be consistent.

### Step 7c.7: Preparation of a remote sensing method as an annex to the project description

Remote sensing analysis is an evolving field and will be performed several times during the project term. A consistent time-series of data must emerge from this process.

To achieve a consistent time-series, the risk of introducing artifacts from method change must be minimized. For this reason, the detailed methodological procedures used in pre-processing, classification, post classification processing, and accuracy assessment of the remotely sensed data, must be carefully documented in an annex to the project description. In particular, the following information must be documented:

1. Data sources and pre-processing: Type, resolution, source and acquisition date of the remotely sensed data (and other data) used; geometric, radiometric and other corrections performed, if any; spectral bands and indexes used (such as NDVI); projection and parameters used to geo-reference the images; error estimate of the geometric correction; software and software version used to perform pre-processing tasks; etc.
2. Data classification: Definition of the value classes; classification approach and classification algorithms; coordinates and description of the ground-truthing data collected for training purposes; ancillary data used in the classification, if any; software and software version used to perform the classification; additional spatial data and analysis used for post-classification analysis, including class subdivisions using nonspectral criteria, if any; etc.
3. Classification accuracy assessment: Accuracy assessment technique used; coordinates and description of the ground-truth or high resolution data collected for classification accuracy assessment; post-processing decisions made based on the preliminary classification accuracy assessment, if any; and final classification accuracy assessment.
4. Method changes: If in subsequent monitoring periods changes will be made to the original remote sensing method:
   * Each change and its justification must be explained and recorded; and
   * When methods change, at the moment of change, theentire time-series of past estimates that is needed to update the baseline must be recalculated using the new method.

### Step 8: Determine the drivers and agents influencing the variable

**Goal**: Determine the drivers and agents influencing the variable. Document the steps taken, data sources used, and degree and sources of potential uncertainty.

**Methods and guidance**: This step is not required for planned or controlled variables, since we know who is driving change in the variables in those cases, and can enquire directly as to what they are planning and why. This is only required for systematic variables.

For systemic variables, understanding why the variable *X* has the values it does, what is driving changes in the variable *X* (drivers and underlying causes), and “who” is acting in ways that change the variable *X*

(the “agents”) is necessary for two main reasons: (i) Estimating the quantity and location of future change in the variable *X*; and (ii) Designing effective measures to change the future trajectory of *X*, if this is one of the project goals (for instance, increasing soil carbon). Understanding the drivers, causes and agents may also be critical to designing project activities and leakage prevention measures.

This analysis must be performed through the following six sub-steps[[7]](#footnote-9):

1. Identification of the reference condition of the variable
2. Identification of agents of change in the variable;
3. Identification of drivers of change in the variable;
4. Identification of underlying causes;
5. Analysis of chain of events leading to changes in the variable;
6. Conclusion

### Step 8a: Identification of the reference condition of the variable

This step is to be undertaken only for location specific variables. If the variable in question is process specific, proceed to Step 8b.

For location specific variables, identify the reference condition, which is often the expected condition of the ecosystem after the completion of the project. The reference condition should be similar to some condition which existed at a prior time, before ecosystem degradation occurred, and which serves to define the target which the project hopes to achieve. For instance, if the project is expected to improve soil carbon through the removal of invasive trees and non-native species, and the re-establishment of native grasslands, the reference condition is probably the condition of the site prior to invasion of woody and non-native plants, and the degradation of the grasslands. Identify as well a reference time, which is the time in the past at which the reference condition existed. The project proponent must document:

* When in the past the project area was in a condition similar to the desired condition.
* What the project area looked like at that time, in terms of species composition, soil characteristics, ecosystem processes, etc.

This reference time may be a time prior to the commencement of intensive management by humans, or under some earlier management regime, or at some time in the past under the current management regime.

Document what evidence there is to support the selection of the reference time, and what evidence there is of the condition of the project area at that time.

Global change may make identification of reference conditions and reference times within the area very difficult (e.g., if changes in precipitation patterns mean that the species mix in the future will be different than that which has ever existed in the past within the area.) In this case the reference condition should be the condition which existed prior to the commencement of significantly degrading activities in the area, even if this condition is unlikely to be achieved in the future.

Note that in some cases the reference condition may be the present condition. For instance, where degradation of an ecosystem has not yet occurred, but is forecast to occur in the future, the reference condition is the current condition.

### Step 8b: Identification of agents of change

Identify the main agent groups of change in the variable *X* (e.g.farmers, ranchers, loggers, planners or recreational users) and their relative importance (i.e. the amount of historical change in the variable *X* that can be attributed to each of them).

For location specific variables, the agents identified must include those identified as responsible for the change of the condition of the area from the reference condition to the current condition, but may also include other agents, including those who may be tending to drive the land back toward the reference condition.

For process specific variables, the agents identified must include those responsible for undertaking or maintaining the processes.

Agents identified should have relatively direct influence on the changes in the variable. Thus for instance a farmer on the land, or a zoning committee establishing land use guidelines, or an upwind industrial plant releasing emissions causing acid rain to fall on the area could be an agent, but a consumer buying meat produced on the land would probably not be. For this reason, it is possible that for some variables there will be no agents. For instance, if the variable in question is precipitation, which may vary as global warming occurs, the people responsible for global warming (all of us, more or less!) would not be agents.

Agents identified should have actual influence over changes in the variable. Thus for instance if a zoning committee establishes guidelines for land use, but they are almost never followed, the zoning committee is not be an agent.

To do this identification, use existing studies, historical records, maps, expert-consultations, field-surveys and other verifiable sources of information, as needed.

Determine the relative importance of each agent identified. Rate importance only in terms of the amount of direct influence that they have over events within the project area which will cause or inhibit changes in the variable.

If the relative importance of different agents is spatially correlated (e.g. small farmers are concentrated in the hills, while ranchers are on the plains), it may be useful to stratify the areaaccordingly, in order to recognize the different effects on the variable of the different agents.

For each identified agent group, provide the following information:

1. Name of the main agent group or agent.
2. Description of what the agent does to cause or inhibit change in the value of the variable *X.*
3. Brief description of the main social, economic, cultural and other relevant features of each main agent group. Limit the description to aspects that are relevant to understand why the agent group is deforesting.
4. Brief assessment of the most likely development of the population size or influence of the identified main agent groups.
5. Statistics on historical change in the variable attributable to each main agent group in the area.

### Step 8c: Identification of drivers of change in the variable

For each identified agent group, analyze factors that drive their decisions. The goal is to identify the immediate causes of change in the variable, both historically and currently. Where no agents were identified in Step 8b, go to Step 8d.

Two sets of driver variables have to be distinguished:

1. Drivers explaining the quantity of change in the variable, such as:
   * Prices of agricultural products,
   * Costs of agricultural inputs,
   * Population density, or  Rural wages.
2. For location specific variables, identify the drivers explaining the location of change, also called 6

“predisposing factors” (de Jong, 2007 ), such as:

* + Accessibility (such as vicinity to existing roads, railroads, navigable rivers and coastal lines),
  + Slope,
  + Proximity to markets,
  + Proximity to existing or industrial facilities (e.g. sawmills, pulp and paper mills or agricultural products processing facilities),
  + Proximity to water,
  + Proximity to existing settlements,
  + Land title history,
  + Differences in soil depth, fertility, precipitation, or
  + Management category of the land (e.g. National Park or indigenous reserve).

For each of these two sets of variables:

1. List key drivers and provide any relevant source of information that provides evidence that the identified drivers influence change in the variable.
2. Briefly describe for each main agent group identified how the key drivers have and will most likely impact on each agent group’s decisions and actions.
3. For each identified key driver provide information about its likely future development, by providing any relevant source of information.

6 De Jong, B.H.J.; Bazan, E. Esquivel; Quechulpa Montalvo, S. Application Of The Climafor Baseline To Determine Leakage: The Case Of Scolel Te. Lawrence Berkeley National Laboratory, 2007.

1. For each identified driver briefly describe the project measures that will be implemented to address them, if applicable.
2. Rank the identified drivers in terms of the degree of influence that they have had and are expected to have on change in the variable.

### Step 8d: Identification of underlying causes of change in the variable *X*

The agents’ characteristics and decisions, or the changes in the variables themselves, where no agents are identified, are themselves determined by broader forces, the underlying causes of change, such as:

* Land-use policies and their enforcement,
* Population pressure,
* Poverty and wealth,
* War and other types of conflicts,
* Property regime, or
* Spread of invasive species.

Document these causes using the following steps:

1. List the key underlying causes and cite any relevant source of information that provides evidence that the identified factors are an underlying cause for change in the variable.
2. Briefly describe how each key underlying cause determines or influences the key drivers identified in Step 8c and the decisions of the main agent groups identified in Step 8b, if agents and drivers have been identified.
3. For each identified key underlying cause provide information about its likely future development, by citing any relevant source of information.
4. For each identified underlying cause describe the project measures that will be implemented to address them, if applicable.
5. Rank the identified causes in terms of their historic and expected future impact on change of the variable.

### Step 8e: Analysis of chain of events leading to change in the variable *X*

Analyze the relations between main agent groups, key drivers and underlying causes and explain the sequence of events that typically leads to or inhibits change in the variable. Determine the relative ranking of importance of the agents, drivers and causes. Consult local experts, literature and other sources of information, as necessary. Briefly summarize the results of this analysis in the project description. At the end, provide a concluding statement from the above analysis (Steps 3.1-3.4) about the most likely future evolution of the variable *X* in the area.

### Step 8f: Conclusion

Step 8 must conclude with a statement about whether the available evidence about the most likely future trend in change in the variable *X* within the area is:

* Inconclusive; or
* Conclusive. In order to be conclusive, the analysis of chain of events undertaken in Step 8e must show that at minimum 80% of the identified drivers, agents and causes are tending to drive the future trend in change in the variable *X* in the same direction, and that the relative ranking points to these drivers agents and causes as being the key drivers of change.

In the case where the evidence is conclusive, state whether the weight of the available evidence is sufficient to allow quantitative estimation of the future value of the variable, and if so, why.

### Step 9: Reassess the category of variable being projected

**Goal:** Based on the work undertaken in the previous steps, reassess whether the previous determination of the category of the variable, undertaken in Step 3, remains correct, or whether information gathered in subsequent steps makes it likely that the variable should fall into a different category than that originally determined. Document the steps and data used to make this determination.

**Methods and guidance**: The category of the variable being examined was determined on a preliminary basis in Step 3. However, work undertaken in Step 8 may cause a reassessment of the category of the variable. As well, many variables fall into more than one category, based on the types of drivers, agents and causes influencing that variable. For each identified driver, agent or cause, note the expected degree of influence on the value of the variable *X* that it has, as determined in Step 8.

The category of the variable is determined by identifying the degree of importance of the agents, drivers and causes falling to each of the three categories – controlled, planned and systemic, using the flowing decision key, as follows:

* If substantial control (control of more than 75% of the change in the variable) in the future under the scenario being examined is exerted by the project proponent or by agents under his or her control, then the variable is controlled. If not, then:
* If substantial control (control of more than 75% of the change in the variable) in the future under the scenario being examined is exerted by one or more known agents who act independently of the project proponent, and who have the direct ability to cause or influence the change in the variable, the variable is planned. If not, then  The variable is systemic.

### Step 10 Analysis of constraints to future values of the variable *X*

**Goal**: Determine what physical, social, economic or other constraints exist which limit the possible values of the variable. Document the data and methods used to make these determinations.

**Methods and guidance:**Projection of future values for the variable must recognize any limits which exist to the upper or lower plausible values of the variable. These constraints can be caused by physical, biological, logistical, economic or other limitations. For example:

1. Land use constraints: If changes in the variable result in whole or part from human activities or management, there may be biophysical and infrastructure constraints (soil, climate, elevation, slope, distance to roads, supply of an input etc.) that limit the geographical area wherethe management or activity could plausibly take place. These constraints could act by creating absolute limits, or by creating limits perceived by the main agents of change.
2. Economic constraints: Even if there are no immediate biophysical constraints, there may be limits to resources which slow the pace of change, or some change could plausibly occur, but would in fact result in uneconomic activities, and therefore are unlikely to occur.
3. Physical constraints: There may be physical limits to the possible values which the variable can take.
4. Institutional constraints: An activity leading to change in the variable may be possible and economically viable, but forbidden by laws which are enforced, or by custom, or may be made unlikely by limits in institutional capacity.

Limits may be of two sorts:

* Absolute. Absolute limits are points beyond which the variable cannot go (for instance, soil carbon levels less than zero), or is quite unlikely to go (for instance, tree biomass accumulations above the limits set by the ecosystem and the species mix). Note that limits to variables such as tree biomass may not be absolute – for instance, an ecosystem could at times exceed the normal maximum value – but can be treated as such for the purposes of projecting values of the variable, since exceeding these limits is relatively unlikely.
* Break points. Break point limits are limits at which the rate of change of the variable will change. For instance:
  + A situation in which change in a variable beyond a certain value requires a different biological process with different process rates than that occurring before the breakpoint was reached.
  + There exists a point at which all of the good agricultural land will have been deforested, after which different agents will undertake deforestation of marginal land for a different use and at a different rate.

The project proponent must research and document the likely constraints to the plausible values of the variable. These may be very simple (for instance, the project cannot burn less than no fuel) or they may be very complex (for instance limits to deforestation within a broad landscape with many land use processes under way). Some variables may also be effectively unlimited in their upper, lower, or both values. Note also that some variables may have both absolute limits and break points prior to reaching the absolute limit.

### Step 11: Projection of controlled variables

**Goal**: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the controlled variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

**Methods and guidance**: Controlled variables will generally be projected as part of the completion of the ex-ante project scenario projection (Task 3 in module *VM0021 Soil Carbon Quantification Methodology*). In this case, projection of the variable will reflect the project’s planned actions and results. Project proponents should make these projections based on a project plan which considers feasibility, costs, and potential performance risks. Projected values of the variable must reflect these considerations.

In rare circumstances, controlled variables may occur in projections made as part of Task 2 in *VM0021 Soil Carbon Quantification Methodology*, the ex-ante baseline. In these cases, project proponents must independently verify that the projected values of the variables are consistent with those which would be expected were the variable systemic or planned, rather than controlled. Project proponents are therefore required to complete the work laid out in Steps 5, 6 or 7 as appropriate, 8 and 9, and 12 or 13 as appropriate, and must demonstrate that the projected values of the variable are no less conservative than those which would be projected if the variable were systemic.

### Step 12: Projection of planned variables

**Goal**: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the planned variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

**Methods and Guidance**: Planned variables occur when specific agents not under the control of the proponent have stated plans for the value of the variable. These stated plans may be used as the projected values providing the following conditions are met:

1. The stated plans are feasible given the agent’s abilities and resources.
2. The stated plans are consistent with local, regional, or sectoral practice and history. In order to demonstrate this, the project proponent may need to undertake some or all of the work outlined in Steps 5 through 9 of this module.
3. The stated plans were made prior to the commencement of the design of the carbon project. If this is not the case, the project proponent must demonstrate that the plans were made independent of, and ideally without knowledge of, the carbon project.
4. The agent making the plans does not stand to gain directly from the carbon project, and it can be demonstrated that the plans were not made in the expectation of such a gain.

If these conditions cannot be met, project proponents are required to demonstrate that the projected values of the variable based on the agent’s plans are no less conservative than those which would be projected if the variable were systemic, and must therefore complete the work laid out in Steps 5, 6 or 7 as appropriate, 8 and 9, and 12 or 13 as appropriate.

### Step 13: Projection of process specific systemic variables

**Goal**:Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the process specific variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

**Methods and guidance**: Projection of process specific systemic variables must be undertaken using one of three techniques for projecting the future values of the variable.

* Linear extrapolation: Projection of the existing trajectory of change in the value of the variable into the future. In general, this is the simplest approach. This approach is applicable where the project proponent believes that the drivers, agents and causes leading to change in the variable within the stratum are likely to remain relatively unchanged in the future.
* Modified trajectory: Projection of the future values of the variable based on the existing trajectory, modified to reflect the expected impacts of changes in one or two relatively independent drivers, agents or causes. This technique is much less complex than the modeled technique, while still integrating the effects of expected changes in the factors influencing the variable.
* Modeled: Projection of future values of the variable based on a function or model which integrates the impacts of multiple drivers, agents and causes on the variable. This technique is typically highly data intensive, since the project proponent must have enough data on past changes in the variable and changes in drivers, agents and causes to determine the causal relationships within the system. When this technique is used, the data on past values of the variable is used to develop and truth the model. This technique may be particularly suitable where existing models have been developed and peer reviewed in the scientific literature for forecasting changes in the variable. Currently, models such as Geomod are useful for modeling of this sort, but project proponents should use the best available models currently available at the time of the project.

Based on the data generated on the variable, the processes influencing its value, and the degree to which knowledge of the processes leading to change in the variable exists, choose the most suitable technique, and document the reasons for the choice.

### Step 13b: Linear extrapolation

The linear extrapolation method is used where the project proponent has evidence to support the supposition that the existing trend line of change in the variable will continue into the future. Thus for instance if non-tree woody biomass has been increasing steadily at a rate of 0.01 t /ha/yr throughout the historic period examined, the project proponent may propose that this will continue into the future. The linear extrapolation may be based on a straight line, as in the example given, or may be based on a curve extracted from the historic information. The steps in the linear extrapolation method are:

### Step 13b.1: Project existing curve

Based on the curve extrapolated from the historic data, project values for the variable *X* in the stratum for each future time point analyzed within the project crediting period.

### Step 13b.2: Check for conservatism

Based on the analysis of agents, drivers and causes, the project proponent must determine and document whether there are any reasonably possible changes in the status of these factors which might cause the use of the trajectory to be non-conservative. If any such factors are noted, the project proponent must use the modified trajectory method given in Step 13c, or the modeled method given in Step 13d, rather than the linear extrapolation method.

### Step 13b.3: Check for limits of possible values of the variable

Based on the work undertaken in Step 9, check whether the values for X based on the linear extrapolation reach a limit of the possible values of the variable. If no limit is reached, use the values derived from the historic curve as the projected values of the variable.

If an absolute limit is reached, all values of the variable above an upper limit or below a lower limit must default to the limit value, and the revised values are the projected values.

If a break point is reached, the project proponent must adjust the future curve from that point onwards to reflect the altered dynamics of the variable beyond the breakpoint, and repeat Steps 1 through 3 for this new curve.

### Step 13c: Modified trajectory

The modified trajectory technique uses the same steps and methods as those given in section 13b for the linear extrapolation technique above, except that the following steps are undertaken prior to undertaking Step 13b.1:

**Step 13c.1: Identify modifiers**

Identify the key drivers, agents or causes which are expected to modify the trajectory.

### Step 13c.2: Assess conditions of effect

Assess the conditions under which each identified driver, agent or causes is expected to modify the trajectory.

### Step 13c.3: Document expected future values

Document the expected future values of the drivers, agents or causes. Demonstrate that these projected values are supported by assessments by independent agencies or parties, or that they are derived from documented assessments of related drivers or causes. Demonstrate that the projected future values of the drivers and causes are conservative projections.

### Step 13c.4: Modify the trajectory

Modify the trajectory of the variable based on those projected future values of the drivers, agents or variables which are well backed by independent projections, interpreted conservatively.

### Step 13d: Modeled Step 13d.1: Current conditions

Document the current condition of all significant agents and drivers. The modeled approach depends on clear knowledge of the conditions and trends in the agents and drivers influencing the variable. The project proponent must document the current conditions of these drivers and variables. Any information on the past status of the drivers and variables, derived from studies, oral history, government statistics, the remote sensing analysis undertaken in Step 7, and other sources used to determine past status must be documented.

### Step 13d.2: Correlation

Determine correlation between values of the variable and identified agents and drivers. Quantitative relationships must now be derived between the drivers and agents and the values of the variable. Typically this will involve some form of multi-factorial analysis. This step should rely to some degree on existing studies of the drivers of change in the variable, but must also include an analysis of these relationships based on the historic documentation of change in the value of the variable, determined in Steps 6 and 7, and the historic trends in the drivers, determined in Step 8.

### Step 13d.3: Modeling

Model expected current conditions based on these correlations. Based on the current conditions of the agents and drivers, and the proposed model, a projection of current conditions from the model must be undertaken to determine how well it correlates with the actual current values of the variable.

### Step 13d.4: Review

Identify discrepancies, look for possible causes, finalize model. If tests of the model or models show significant discrepancies from actual conditions, or appear to forecast conditions which are highly improbable in the future, the models must be re-examined, and corrections made. The assumptions behind all elements of the model, and the reasons for all changes made to it, must be documented.

### Step 13d.5: Project

Conservatively determine expected future values of drivers and agents used as model inputs for the first monitoring period, and project values of the variable for that time. Determine the future values of drivers and agents for the first monitoring period. The reasons for the projections of these values, and a justification of the conservativeness of these projections, must be documented. Based on these projected values, determine the value or values of the variable at the time of the first future verification period.

### Step 13d.6: Create a time series

Repeat Step 13d.5 for each future monitoring period. The result will be a series of values covering at least the entire project crediting period.

### Step 14: Projection of location specific systemic variables

**Goal**: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the location specific systemic variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

**Methods and guidance**: The objective of this step is to project, for each future time period of interest, the estimated value of the variable *X* across the area.

Depending on the nature of the variable, projections must be made either:

* Using a stratified approach, where the values of the variable at any given point in time will be projected to be the same for all locations within the stratum area.
* Using a location specific approach, where variation in the value of the variable across the area will be quantified down to some minimum polygon size or pixel resolution. In this case the analysis may still be undertaken on a stratum by stratum basis, but the projected values of the variable will vary within a given stratum.

In general, it is strongly recommended within this methodology, to use a stratified approach. In many cases the amount of data, knowledge of systemic processes and patterns, and the sophistication of the modeling required to achieve projection using the location specific approach will exceed what can reasonably be provided. However, variables may exist for which meaningful stratification is difficult to achieve, and for which modeling capacity may make the location specific approach suitable.

The outputs for the two approaches will therefore be:

* For the stratified approach, a map of the projected stratification for the variable for each time period analyzed, and a value for the variable for each stratum for each time period analyzed. Because in many cases the values of the drivers for the variable may change from time period to time period, the stratification can also change through time. Thus for example if the variable in question is the percentage of area deforested, the strata will be established based on differences in the deforestation rate, and each stratum will have an associated total area deforested, associated percentage area deforested, and annual percentage deforestation rate. If population is one of the drivers of deforestation, and if future changes in the location of population in the area are forecast, stratification may also change over time.
* For the location specific approach, a map of the locations at which specific values of the variable are projected to exist, shown either as pixels or as polygons. And an associated value for the variable for each pixel or polygon.

### Step 14a: Determine the approach to be used

The project proponent must choose whether to use the stratified approach or the location specific approach. As discussed above, the stratified approach is recommended in most cases.

The exception to this guidance may occur if the project proponent believes that the location (as versus the quantity) of changes in the value of the variable is highly correlated with a single driver. For instance, if deforestation is highly correlated with land quality, the project proponent may be able to extrapolate the likely locations of deforestation by projecting that the best land will be deforested first.

### Step 14b Determine proposed projection technique

Three techniques for projecting the future values of the variable may be used:

* Linear extrapolation: Projection of the existing trajectory of change in the value of the variable into the future. In general, this is the simplest approach. This approach is applicable where the project proponent believes that the drivers, agents and causes leading to change in the variable within the stratum are likely to remain relatively unchanged in the future.
* Modified trajectory: Projection of the future values of the variable based on the existing trajectory, modified to reflect the expected impacts of changes in one or two relatively independent drivers, agents or causes. This technique is much less complex than the modeled technique, while still integrating the effects of expected changes in the factors influencing the variable.
* Modeled: Projection of future values of the variable based on a function or model which integrates the impacts of multiple drivers, agents and causes on the variable. This technique is typically highly data intensive, since the project proponent must have enough data on past changes in the variable and changes in drivers, agents and causes to determine the causal relationships within the system. When this technique is used, the data on past values of the variable is used to develop and truth the model. This technique may be particularly suitable where existing models have been developed and peer reviewed in the scientific literature for forecasting changes in the variable.

Based on the data generated on the variable, the processes influencing its value, and the degree to which knowledge of the processes leading to change in the variable exists, choose the most suitable technique, and document the reasons for the choice.

### Step 14c: Check stratification

At this point review the proposed stratification of the area. Based on the data gathered to this point, the choices of approach and technique must be undertaken, based on the following guidance:

* If either the linear extrapolation technique or the modified trajectory technique has been chosen, ensure that the stratification recognizes any changes in drivers, agents or causes across the area that are likely to result in significant changes in the value of the variable. It is highly recommended that if these techniques are used, a stratified approach should also be used, making it important to ensure that the strata reflect the significant drivers, agents and causes.
* If the modeled technique has been chosen, and the location specific approach will be used, project proponents may consider reducing the number of strata to reflect the fact that the model will account for many of the changes in drivers, agents and causes across the area, and the locations of change will be determined at a substratum level. It is possible that if the modeled technique and location specific approach are used, the entire area of interest can be considered a single stratum, unless the differences in processes across the area require the preparation of more than one model.

### Step 14d: Linear extrapolation

The linear extrapolation method is used where the project proponent has evidence to support the supposition that the existing trend line of change in the variable will continue into the future. Thus for instance if non-tree woody biomass has been increasing steadily at a rate of 0.01 t /ha/yr throughout the historic period examined, the project proponent may propose that this will continue into the future. The linear extrapolation may be based on a straight line, as in the example given, or may be based on a curve extracted from the historic information. The steps in the linear extrapolation method are:

### Step 14d.1: Project existing curve

Based on the curve extrapolated from the historic data, project values for the variable *X* in the stratum for each future time point analyzed within the project crediting period.

### Step 14d.2: Check for conservatism

Based on the analysis of agents, drivers and causes, the project proponent must determine and document whether there are any reasonably possible changes in the status of these factors which might cause the use of the trajectory to be non-conservative. If any such factors are noted, the project proponent must use the modified trajectory method given in Step 14e, or the modeled method given in Step 14f, rather than the linear extrapolation method.

### Step 14d.3: Check for limits of possible values of the variable

Based on the work undertaken in Step 9, check whether the values for X based on the linear extrapolation reaches the limit of the possible values of X. If no limit is reached, use the values derived from the historic curve as the projected values of the variable.

If an absolute limit is reached, all values of the variable above an upper limit or below a lower limit must default to the limit value, and the revised values are the projected values.

If a break point is reached, the project proponent must adjust the future curve from that point onwards to reflect the altered dynamics of the variable beyond the breakpoint, and repeat Steps 1 through 3 for this new curve.

If the values of the variable are being determined using a stratified approach, no further work is required. Since linear extrapolation does not depend on modeling which would allow the calculation of specific values for a specific point, the location specific approach should not be used. The one exception might be in the case of a variable of only two possible values (for instance, deforested or not deforested), with location specific breakpoints such as good soil quality versus marginal soil quality. Even in these cases, it is recommended that the projections be undertaken on a stratified basis, with the stratification adjusted to recognize the location specific breakpoints. If however, the project proponent believes that use of a location specific approach is required, they must undertake the work described in Step14f to develop the modeling tools to allow location of the changes in the values of the variable within the stratum.

### Step 14e: Modified trajectory

The modified trajectory technique uses the same steps and methods as those given in Step 14d for the linear extrapolation technique above, except that the following steps are undertaken prior to undertaking Step 14d.1.

**Step 14e.1: Key modifiers**

Identify the key drivers, agents or causes which are expected to modify the trajectory.

### Step 14e.2: Modifying conditions

Assess the conditions under which each identified driver, agent or causes is expected to modify the trajectory.

### Step 14e.3: Expected future values

Document the expected future values of the drivers, agents or causes. Demonstrate that these projected values are supported by assessments by independent agencies or parties, or that they are derived from documented assessments of related drivers or causes. Demonstrate that the projected future values of the drivers and causes are conservative projections.

### Step 14e.4: Modify

Modify the trajectory of the variable based on those projected future values of the drivers, agents or variables which are well backed by independent projections, interpreted conservatively.

### Step 14f: Modeled Step 14f.1: Current conditions

Map or document the current condition of all significant agents and drivers. The modeled approach depends on clear knowledge of the conditions and trends in the agents and drivers influencing the variable. The project proponent must document the current conditions of these drivers and variables. Any information on the past status of the drivers and variables, derived from studies, oral history, government statistics, the remote sensing analysis undertaken in Step 7, and other sources must also be documented.

### Step 14f.2: Correlate

Determine correlation between values of the variable and identified agents and drivers. Quantitative relationships must now be derived between the drivers and agents and the values of the variable. Typically this will involve some form of multi-factorial analysis. This step may rely to some degree on existing studies of the drivers of change in the variable, but must also include an analysis of these relationships based on the historic documentation of change in the value of the variable, determined in Steps 6 and 7, and the historic trends in the drivers, determined in Step 8.

### Step 14f.3: Check model against current conditions

Model expected current conditions based on these correlations. Based on the current conditions of the agents and drivers, and the proposed model, a projection of current conditions from the model must be undertaken to determine how well it correlates with the actual current values of the variable. Note that the model derived and developed in Step 14f.2 and this step may be unique for each stratum, or may be the same across all strata, in which case the differences in the strata will arise solely from differences in the values of one or more agents or drivers between the strata.

### Step 14f.4: Review and revise model

Identify discrepancies, look for possible causes, finalize model if tests of the model or models show significant discrepancies from actual conditions, or appear to forecast conditions which are highly improbable in the future, the models must be re-examined, and corrections made. The assumptions behind all elements of the model, and the reasons for all changes made to it, must be documented.

### Step 14f.5: Model future values

Conservatively determine expected future values of drivers and agents used as model inputs for the first monitoring period, and project values of the variable for that time. Determine the future values of drivers and agents for the first monitoring period. The reasons for the projections of these values, and a justification of the conservativeness of these projections, must be documented. Based on these projected values, determine the value or values of the variable at the time of the first future verification period.

### Step 14f.6: Project stratification changes

For variables which are being projected on a stratified basis, project the location of any changes in the stratification which may result from the modeling or from projected changes in drivers or agents.

### Step 14f.7: Project location specific values

For variables which are being projected on a located basis, project the value of the variable for each point or polygon. These projections can be accomplished using programs such as Geomod, or custom programs or approaches.

### Step 14f.8: Model a time sequence

Repeat Step 14f.5, 14f.6, and, if used, 14f.7 for each future monitoring period. The result will be a series of values covering at least the entire project crediting period.

# 6 PARAMETERS

|  |  |
| --- | --- |
| Data Unit / Parameter: | *X* |
| Data unit: | Varies |
| Description: | The variable for which a projection of future values is being made |
| Source of data: | Future values determined using the methods given in the module |
| Justification of choice of data or description of measurement methods and procedures applied: | N/A |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,49 (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada)

De Jong, B.H.J.; Bazan, E. Esquivel; Quechulpa Montalvo, S. (2007) Application Of “The Climafor Baseline” To Determine Leakage: The Case Of Scolel Te. Lawrence Berkeley National Laboratory http://escholarship.org/uc/item/3f68q2wh;jsessionid=5EC491008DE4BE3DAC334979C0DB9370#page-1 (last visited 16-09-2011)

Angelsen and Kaimowitz (1999) Rethinking the Causes of Deforestation: Lessons from Economic Models, World Bank Res Obs 14 (1): 73-98.

Chomitz, K. M., G. A. B. Da Fonseca, K. Alger, D. M. Stoms, M. Honzák, E. Charlotte Landau, T. S. Thomas, W. Wayt Thomas, and F. Davis. 2006. Viable reserve networks arise from individual landholder responses to conservation incentives. Ecology and Society 11(2): 40. (Last visited: 19-09-2011 URL: [http://www.ecologyandsociety.org/vol11/iss2/art40/)](http://www.ecologyandsociety.org/vol11/iss2/art40/)

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-3

METHODS TO DETERMINE THE PROJECT BOUNDARY

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## Table of Contents

[1 SOURCES 2](#_Toc10345)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc10346)

[3 DEFINITIONS 2](#_Toc10347)

[4 APPLICABILITY CONDITIONS 3](#_Toc10348)

[5 PROCEDURES 3](#_Toc10349)

[6 PARAMETERS 5](#_Toc10350)

[7 REFERENCES AND OTHER INFORMATION 5](#_Toc10351)

# 1 SOURCES

Adapted from: Draft Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation, author Lucio Pedroni

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

Brown, S., F. Achard, R. de Fries, G. Grassi, N. Harris, M. Herold, D. Mollicone, D. Pandey, T. Pearson,

D. Shoch, 2007. Reducing Greenhouse Gas Emission from Deforestation and Degradation in Developing Countries: A Sourcebook of Methods and Procedures for Monitoring, Measuring and Reporting (Draft Version, 10.November, 2007).

# 2 SUMMARY DESCRIPTION OF THE MODULE

The module sets out the methods and standards by which the temporal and spatial boundaries of the project are to be defined and documented, and the criteria for selecting carbon pools and GHG emissions to be monitored.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Baseline:** | The total amount of carbon within the project boundary in absence of the project. |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project boundary in the absence of the project. |
| **Directly**  **Attributable:** | The change or effect occurs as result of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be primarily and directly caused by the previous event in the chain. Analysis of the linkages in the chain should show that for each one, the previous event is at least 75% responsible for the next event. For this reason, the relationship between an event, or the actions of an agent, and the directly attributable effect, typically consist of not more than a few causal linkages. |
| **Ex-ante:** | Before the fact. Projection of values or conditions in the future. |
| **Ex-post:** | After the fact. Estimation of values or conditions in the present or past. |
| **Leakage:** | See *VCS Program Definitions*. |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Project Crediting Period:** | See *VCS Program Definitions*. |
| **Project Scenario:** | The actions and events which are expected to occur as a result of |

implementing the project.

|  |  |
| --- | --- |
| **Project Start Date:** | See *VCS Program Definitions*. |
| **Significant:** | A pool or source is significant if it does not meet the criteria for being deemed *de minimus*. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

The procedures described in the sub-sections below entail the following inputs and outputs.

Inputs:

* General knowledge of project area and expected conditions under the baseline and project scenarios;
* Maps of the region within which the project occurs, ideally consisting of layers in a GIS showing geographic and cultural features;
* Geo-referenced data points delineating the project area; and,
* Knowledge of the range of the permissible project crediting periods as set out in the latest version of the *VCS Standard.*

Outputs:

* Geo-referenced definition of the project area;
* Documented project start date;
* Documented choice of project crediting period;
* Documented projection of the monitoring periods;
* Documented choice of carbon pools to be accounted; and,
* Documented choice of sources of GHG emissions to be accounted.

### 5.1 Spatial boundaries

Define the boundaries of the following spatial feature:

**5.1.1** Project area:

The project area is the area or areas of land on which the project proponent will undertake the project activities. Lands on which the project activity will not be undertaken cannot be included in the project area.

Describe and justify the criteria used to define the boundary of the project area. Use appropriate sources of spatial data for each of these criteria, such as remotely sensed data, field information, and other verifiable sources of information meeting the requirements laid out in the latest version of the *VCS Standard*.

Provide project location in KML file and geodetic polygons, as well as additional shape files, maps, GPS coordinates or any other location information that allows the identification of the boundaries unambiguously and with a reasonable level of certainty.

### 5.2 Temporal boundaries

Define the temporal boundaries listed below:

**5.2.1** Project start date and end date of the project activity

The duration of the project activity must fall within the permissible range as set out in the most recent version of the *VCS Standard*.

**5.2.2** Starting date and end date of the project crediting period

The crediting period must fall within the permissible range as set out in the most recent version of the *VCS Standard*.

**5.2.3** Monitoring period

The minimum duration of a monitoring period is one year.

### 5.3 Carbon pools

Selection of carbon pools to be accounted must conform with requirements for the project type, given in the most current version of the VCS document *Agriculture, Forestry and Other Land Use (AFOLU) Requirements*.

Where pools are indicated as optional in the *AFOLU Requirements*, further guidance on the selection of carbon pools can be found in the GOFC-GOLD sourcebook (Brown *et al.*, 2007)[[8]](#footnote-10).

### 5.4 Sources of GHG emissions

The four sources of GHG emissions listed in Table 2 are eligible. The inclusion of a source is to be decided (TBD) by the project proponent taking into account the specific project circumstances and the guidance provided below.

**Table 2.** Sources and GHG included or excluded within the project boundary

|  |  |  |  |
| --- | --- | --- | --- |
| **Sources** | **Gas** | **Included/**  **TBD/ excluded** | **Justification / Explanation of choice** |
| Biomass burning | CO2 | Excluded | Counted as carbon stock change |
| CH4 | TBD |  |
| N2O | TBD |  |
| Combustion of fossil fuels by vehicles | CO2 | TBD |  |
| CH4 | Excluded | Not a significant source |
| N2O | Excluded | Not a significant source |
| Emissions from livestock husbandry | CO2 | Excluded | Carbon content is assumed to be sourced from renewable carbon pools with a cycle of less than 1 year, and thus no net addition to atmospheric carbon occurs |
| CH4 | TBD |  |
| N2O | TBD |  |
| Emissions of nitrogen captured by nitrogen fixing plants | CO2 | Excluded | Not a significant source |
| CH4 | Excluded | Not a significant source |
| N2O | TBD |  |

Any source noted as TBD above, and which will emit significantly more GHGs under the project scenario, as compared with the baseline scenario, must be included in the project boundary. Where accounting is not required, the decision on which sources of GHG emission to select depends on presence or absence of emissions from specific sources, available financial resources, ease and cost of measurement, the magnitude of potential change and the principle of conservativeness. The following guidance is given:

* Sources of GHG emissions that are not significant according to the validated ex ante assessment do not need not to be monitored ex post.
* Changes in GHG emissions not associated with carbon stock changes are considered permanent, while carbon stock changes are considered non-permanent under the VCS. For this reason, accounting of changes in carbon stocks and of GHG emissions must be kept separate at all times in this methodology.

# 6 PARAMETERS

None

# 7 REFERENCES AND OTHER INFORMATION

GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,49 (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada)

VCS methodology*VM0015 Methodology for Avoided Unplanned Deforestation*

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

VCS MODULE VMD0021

ESTIMATION OF STOCKS IN THE SOIL CARBON POOL



VMD0021

:

Version 1.0

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 2](#_Toc62215)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc62216)

[3 DEFINITIONS 2](#_Toc62217)

[4 APPLICABILITY CONDITIONS 3](#_Toc62218)

[5 PROCEDURES 3](#_Toc62219)

[6 PARAMETERS 24](#_Toc62220)

[7 REFERENCES AND OTHER INFORMATION 30](#_Toc62221)

# 1 SOURCES

None

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides the methods to be used to estimate the required number of soil plots in each stratum, design and establish the plots, determine the carbon stock in the soil carbon pool, and check the statistical rigor of the results.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Carbon Project:** | See *VCS Program Definitions* for “project”. |
| **Coarse Fragments:** | Pieces of rock or cemented soils > 2mm in diameter, and therefore too large to pass through the screen used in the laboratory prior to laboratory analyses. |
| **Embedded Boulders:** | Rocks which are free of the bedrock, and at least partly embedded in the soil, but which are too large to move manually. |
| **Ex-ante:** | Before the fact. Projection of values or conditions in the future. |
| **Large Coarse Fragments:** | Coarse fragments greater than 10 mm in diameter, and therefore too large to be included in the bulk density sample. |
| **Long Lived:** | Carbon which is in a form such that more than 80% of the carbon will remain in the soil for more than 10 years. |
| **Monitoring Interval:** | The length of time between monitoring events. |
| **Organic Soil** | Soils are organic if they: |

1. Are saturated with water for less than 30 days (cumulative) per year in normal years and are not artificially drained, but contain more than 20 percent (by weight) organic carbon; or
2. Are saturated with water for 30 days or more cumulative in normal years (or are artificially drained) and, excluding live roots, have an organic carbon content (by weight) which is:
   1. 18 percent or more, if the mineral fraction contains 60 percent or more clay; or
   2. At least 12 percent, if the mineral fraction contains no clay; or
   3. Greater than 12 percent plus 0.1 multiplied by the clay percentage (12%+0.1\*clay%), if the mineral fraction contains less than 60% clay.

|  |  |
| --- | --- |
| **Pedogenic:** | Arising from processes occurring within the soil. |
| **Pedogenic Carbonate:** | Inorganic carbon derived from ongoing soil processes. |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Reference Condition:** | A condition of the ecosystem which is believed to have existed at some time, and which reasonably approximates the intended condition which will exist if the project is successful. |
| **Small Coarse Fragments:** | Coarse fragments between 2mm and 10 mm in diameter, and therefore small enough to be included in the bulk density sample. |
| **Soil Types:** | (Or Soil series) The lowest category of U.S. system of soil taxonomy; a conceptualized class of soil bodies (polypedons) that have limits and ranges more restrictive than all higher taxa. Each soil type has soil layers with similar soil color, texture, structure, Ph consistence as  well as mineral and chemical composition. Standardized soil type/series classification systems must be used where available. |
| **Soil Layer:** | Layer of soil whose physical, chemical and/or biological characteristics distinctively differ from the layers below and/or above. |
| **Stratification:** | The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people. |

# 4 APPLICABILITY CONDITIONS

This module is not applicable for sampling or estimation of soil carbon content in organic soils.

# 5 PROCEDURES

### Introduction

The goal of soil sampling is to gather information on soil carbon concentrations with statistical rigor sufficient to permit estimation of the total soil carbon per unit area. Soil sampling must always be conducted on a stratified basis, using the stratification procedures laid out in the module *TRS-1 Methods to determine stratification*. During stratification, existing data such as soil maps, landforms classes, slopes steepness, slope aspects, land cover classifications, and data from previous soil surveys are gathered. The actual work of stratification and estimating soil carbon using this module is undertaken on an overlapping basis, as data from work undertaken in each module refines the work undertaken in the other module.

Stratificationfor soil carbon sampling must consider at minimum the following variables*:*

* Existing soil classifications and mapping
* Soil texture, mineralogy and parent material
* Soil profile depth
* Geomorphic position and related soil processes, including, but not limited to:
  + surface shape (concavity/convexity), o slope position,
  + rates of erosion and deposition, o drainage and water regime,
* Ecology, plant community, and related soil processes, including, but not limited to:
  + Factors which may influence nutrient cycling and inputs, such as nitrogen fixation, rooting intensity and depth, and biomass turnover,
  + Factors which may influence rates of plant mortality and forms of carbon input, such as differences in fire intensity/frequency associated with differences in ecology or plant community.
* Land use and management history and duration
* Fire history and landscape modifications

Soil sampling must be undertaken using a permanent sample plot technique, and a plot design which allows repeated sampling without bias resulting from disturbance caused by previous sampling. Sampling must be undertaken using the following 6 steps:

1. Land reconnaissance and presampling
2. Selection of sampling parameters
3. Identification of sampling requirements
4. Sampling
5. Laboratory procedures and quality assurance
6. Data verification and calculation

### Conditions under which inorganic carbon is accounted

This method contains guidance for quantification of both organic and inorganic carbon in soils. However, in many cases changes in inorganic carbon content are slow and unlikely to be significant. Furthermore, accurate estimation of reductions in atmospheric GHGs due to accretion of inorganic carbon may be difficult, for several reasons:

* Carbonates may be transported from other locations in dust, or in solution, and increases in carbonates in the soil may therefore not represent the formation of new carbonates.
* Available calcium or magnesium for the formation of carbonates may be derived from the breakdown of carbonates at another location.

In general, therefore, it is recommended not to account inorganic carbon under most project scenarios, with the following exceptions:

1. Inorganic carbon must be accounted where project activities are likely to lead to changes in soil chemistry or processes (for instance, increased acidity in the soil), which may be expected to lead to the breakdown of carbonates and the release of carbon compounds to the atmosphere. For instance, under some management regimes ammonium sulfate fertilizer may be added to high pH soils with the goal of reducing pH to a 6.5 to 7.5 range. This pH change will tend to result in the breakdown of inorganic soil carbon and the release of carbon compounds to the atmosphere.
2. Inorganic carbon may be accounted where it can be demonstrated that:
   1. Increases in inorganic carbon in the soil are not the result of the transport of carbonates from outside the project area, or from below the sampled depth, for instance through irrigation or percolation.
   2. Calcium and magnesium for the formation of carbonates are not sourced from breakdown of carbonates outside the project areaor below the sampled depth.

In either case, projection of a baseline for inorganic carbon must take into account the full range of carbonate formation, transport and breakdown processes and environmental conditions. If possible, and if suitable sites are available, strong consideration should be given to the use of a monitored baseline in addition to the ex-ante estimation, due to the complexity of inorganic carbon processes.

### Step 1: Land reconnaissance and pre-sampling

**Goal**: Production of a qualitative assessment of soil carbon variation based on landscape processes and factors, and stratified sampling.

**Product**: Information on the expected values and distribution of soil carbon across theproject area.

**Method:** In this step, theproject area and, if used the reference region, are formally reconnoitered to understand the variability in site conditions in each major soil type (typically major soil types are derived from existing regional or national level soil classification systems, and associated mapping).

For the purpose of preparing an ex-ante estimation of soil carbon levels under the project scenario in Task 3, it may also be desirable to locate and presample reference areas during this step. Sampling of reference area locations where conditions reasonably resemble the soil conditions expected to occur under the project scenario may increase the accuracy of ex-ante projections.

Organize and implement field reconnaissance to observe site conditions, soil types, vegetation types and land uses in the project area, and reference region. During the field visit, mark areas on the aerial photographs (or other maps) that represent a conspicuous difference in the condition of vegetation and soils in each major proposed stratum, fence lines and agricultural field boundaries which may be management unit boundaries, and other conspicuous physical and ecological differences of the land. The reconnaissance must be systematic, and will begin to provide some understanding of changes in soil characteristics across the project area.

The goal of this step is to bring greater definition to the soil and vegetation conditions found in each proposed stratum. This information must be used to refine stratification and plan sampling strategy and intensity.

1. Pre-sampling Strategy: In each proposed stratum, during the reconnaissance period, complete a satisfactory number of soil sampling investigations (follow the procedures in Step 3 below) to determine whether or not the existing proposed stratification of the site is supported in the field, and to gather some information on the range of variation within the project area and stratum. The location of the plots during this step should be determined by deliberate selection of areas thought to be typical of a given proposed stratum, rather than by random or systematic sampling, and statistical assessment of the plot results need not be undertaken.
2. Pre-sampling Soils: In each area sampled, record the soil layers, textural characterization and associated depths of each sample. In each location, triplicate soil pits or probe samples will be required to affirm this characterization following the procedures as in Step 4.
3. Recording Vegetation: In each area sampled, record vegetation composition. The goal is to identify vegetation species and their corresponding percent cover values and communities which may be indicators of soil conditions. Recording vegetation during this phase is aimed at fine tuning soil classification, and not at developing a vegetation classification.

Following pre-sampling, revise the proposed stratification as required, following the techniques given in the module *TRS-1 Methods to determine stratification*. Note also that pre-sampling may be used to identify and eliminate areas containing organic soils, which may be sampled using the methods given below, but must not be accounted using this module.

### Step 2: Selection of sampling parameters

**Goal**: Determination of the sampling parameters.

**Product**: Requirements for sampling intensity and depth, and calculated depth

**Method:**

#### Determining sampling intensity

The number of plots depends on the variation in soil carbon levels, the required level of accuracy and the length of the *monitoring interval*. Based on the pre-sampling work, select an initial number of plots for each stratum. The goal is to install enough plots to meet the required statistical rigor, as discussed in Step 6.4 below. The project proponent may use a number of statistical methods to estimate the expected number of plots required, including those given in Wenger (1984), and in the CDM A/R Methodological Tool *Calculation of the number of sample plots for measurements within A/R CDM project activities* (ARAM Tool 03 Version 02 or later version).

It is possible to reasonably modify (e.g. increase or decrease) the sample size after the pre-sampling or first monitoring event based on the actual variation of the carbon stock changes determined from taking the initial samples. However, the goal is to install sufficient baseline sample plots such that repeated monitoring of these plots can also encompass anticipated increases in variation over time.

#### Determining calculated depth and sampling depth

**Calculated Depth:** For each stratum, determine the calculated depth. This is the depth which will be used in the calculation of total soil carbon. This depth must be determined based on the following criteria:

* The calculated depth must be set to a depth great enough to capture at least 90% of the expected change in soil carbon resulting from the project activity as compared with the projected soil carbon change under the baseline scenario within the project crediting period, or 2m, whichever is less. Identification of the depth above which 90% of the change is expected to occur must be based on current research which has examined changes at depth, since much of the older research limited sampling to 30 cm or less, and did not quantify soil carbon dynamics at depth. Project proponents must start from an expectation of a 1m calculated depth, and adjust to reflect the particular dynamics of the project area. Thus, for instance, if research shows that 90%

of the change in soil carbon resulting from the implementation of the project activity within the project crediting period is expected to occur in the upper 70 cm of the soil, the calculated depth might be set at 70 cm. Determination of the calculated depth must be undertaken based on the available literature, reference area measurements and knowledge of changes in soil carbon under the ecological and treatment conditions expected to apply. Note that some treatments may result in increases in soil carbon in some soil layers, and decreases in soil carbon in others. If this is the case, it is critical to capture both layers in the calculations.

* While bedrock or cemented layers may limit the total depth of the soil in some plots to less than the chosen calculated depth, soil depth in a majority of the plots must be expected to be greater than or equal to the calculated depth.
* The calculated depth must be less than the sampled depth, with the exception of individual plots in which the sampled depth is restricted by bedrock or a cemented layer, in which case the calculated depth may be equal to the sampled depth for that plot.

The calculated depth must be set for each stratum. However, note that within a stratum the actual depth used in the calculations may vary from plot to plot and from time to time due to one of the following conditions:

* Presence of bedrock or a cemented layer at a depth shallower than the calculated depth.
* Changes in soil depth or bulk density, as discussed in Steps 3.1 and 6 below.

**Sampling Depth**: The chosen sampling depth must be greater than the calculated depth, to allow for detection of change caused by the project in deeper layers, and to allow for changes in soil characteristics over time, as discussed in Step 6. Note that as with the calculated depth, the actual depth sampled may be less than the chosen sampling depth if bedrock or cemented layers are present which prevent deeper sampling. Sampling depth must be great enough to ensure that all soil layers where significant changes in soil carbon may occur are sampled. For instance:

* In sites where tillage has been or will be practiced, sampling depth must be great enough to sample both those layers where tillage is occurring, as well as at least one layer below the maximum depth of the tillage, or the crop rooting depth, whichever is greater, to capture effects of downward migration of soil carbon from the tillage and rooting layer.
* In untilled sites, sampling must be deep enough to capture the “C” layer – the soil layer consisting of un-weathered parent material with little organic input. However, where the “C” layer begins more than 2 meters below the soil surface, sampling depth may be limited to 2 meters.

In some cases the examples given above might lead to excessive sampling depths – for instance, in alluvial soils where repeated depositions of soil lead to very deep layers of organically modified soils. In such cases, sampling depth need not be greater than 2 meters. Typically sampling depth should be 10 – 20% greater than calculated depth, to allow for changes in soil density during subsequent sampling events.

Field reconnaissance and digging of a few test pits or probe samples may be required to determine the appropriate sampling depth. The goal of this reconnaissance is to identify the depth to which active and significant modification of the soil carbon is occurring due to both natural and anthropogenic processes. Identifying the depth will therefore require knowledge of the processes impacting the soil, and the reconnaissance will consist of identifying the depth at which these processes are occurring, and will require on expert judgment. Indicators may include process indicators such as active rooting, tillage disturbance, soil color changes indicating active carbon accumulation or leaching, textural changes resulting from mobilization of fine fractions, etc.

### Step 3: Identification of sampling requirements where soil processes exist which may generate inaccuracies in the estimation of soil carbon

**Goal**: Determination of the sampling requirements where soil processes could result in inaccuracies in estimation of GHG effects.

**Product**: Sampling methods which will allow for the adjustments required to compensate for changes in soil density or depth.

**Method:**

Soils are dynamic systems whose properties, such as density, chemistry, depth, and other variables can change over time. The goal of this methodology is to allow accurate estimation of that total amount of carbon in the soils of a site, and changes in that total carbon. Amounts of carbon are determined based on the following 3 key variables:

* The amount of carbon in the soil as a percentage of the mass of the soil.
* The density of the soil (the amount of soil mass per unit volume).
* The volume of soil for which calculations are being done (the depth times the surface area).

The goal of the sampling and calculation methods given in this module is to allow the accurate estimation of changes in atmospheric carbon resulting from changes in soil carbon. For this reason, it is critical to ensure that calculations do not result in erroneous estimations of the amount of carbon removed from or emitted to the atmosphere from soil processes. Such errors may occur for a variety of reasons. The most common potential causes of errors are:

1. Changes in soil density (compaction, accrual of organic matter, tillage, etc.);
2. Apparent changes in soil depth resulting from sampling methods; or,
3. Actual changes in soil depth resulting from erosion or deposition of soils.

The calculation methods to be used are to ensure that false attributions of change in atmospheric carbon do not result from these potential causes of error given in Step 6. However, for changes in soil density and erosion or deposition, changes in sampling technique may need to be undertaken, as detailed below.

### Step 3.1 Changes in soil density

Changes in soil density may occur when soils are subject to treatments such as compaction or tillage, or compositional changes such as that which can occur with increased organic matter. These processes may result in more or less soil being present to the calculated depth, and may thus result in incorrect estimation of the total amount of soil carbon present if not corrected. Where such events are identified as a possible process resulting from the project activity or existing soil processes, the calculated depth may increase over time, and thus the sampling depth must be set to a depth great enough to ensure that sampling captures the data required for the calculations after changes in soil density have occurred.

### Step 3.2 Actual changes in soil depth resulting from erosion or deposition of soils

Where erosion or deposition is expected to occur under the project scenario, project proponents must monitor changes in soil depth arising from these causes, to be able to account for these processes when undertaking calculations. Several techniques may be used, including:

* Installation of pins: Using the plot layout given in Step 4.1 below, select a point which is not expected to be sampled. At this point, during the first sampling of the plot, install a metal rod surface just flush with the top of the mineral soil layer. The metal rod should be longer than the calculated depth, or equal to the depth to bedrock or a cemented layer, whichever is less.

During each sampling, the metal rod must be relocated, and the amount of erosion or deposition (the length of the rod exposed, or the amount of soil above the top of the metal rod) measured.

Care must be taken not to disturb the soil in the area of the rod during each sampling event. Where deposition or accrual has occurred, measurement of the depth of the soil on top of the rod should wherever possible be undertaken using a thin metal probe, to minimize the disturbance of the soil. Where disturbance occurs, the soil must be replaced after measurement.

Note that this technique must not be used where frost heave is expected to occur, or in expansive clay soils, since these processes may change the vertical location of the metal rod, leading to false results.

* Use ground based surveying techniques from known elevation markers to determine changes in elevation to sub centimeter accuracy.
* Use GPS to determine changes in elevation to sub centimeter accuracy.

Along with these techniques, soil profile descriptions must be re-measured by soil layers using standard data forms and procedures given below to determine changes in soil profile and strata thicknesses.

At the same time the bulk density must be estimated using standard techniques given below to distinguish between erosion or deposition and changes soil depth caused by compaction or decompaction, tillage, expanding clays, or other causes.

### Step 4. Sampling

**Goal**: Collection of data which will allow the calculation of a quantitative estimate of soil carbon variation to the degree of statistical precision specified in Step 6.5.

**Product**: Plot data on total soil carbon, and organic and inorganic soil carbon separately.

**Method:**

### Step 4.1 Locating plots

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more “convenient” positions), the permanent sample plots must be located randomly or systematically with a random start within each identified stratum. The geographical position (GPS coordinate); administrative location, and stratum of each plot must be recorded and archived. Also, the sampling plots are to be distributed proportionately. For example, if one stratum consists of three geographically separated sites, then the following steps should be undertaken:

* Divide the total stratum area by the number of expected necessary plots, resulting in the average area per plot.
* Divide the area of each site within the stratum by this average area per plot, and assign the integer part of the result to this site. e.g., if the division results in 6.3 plots, then 6 plots are assigned to this site and 0.3 plots are carried over to the next site, or strata and so on.

Random location of plots can be accomplished in one of two ways:

* Locate plots systematically with a random start. In this case the plots are located using a systematic method – usually on a grid, with the location of the first points on the grid determined randomly. This must be undertaken prior to field work, with the plot locations specified on a map or aerial photos, and locations specified either as distance and direction from a known point or as a GPS coordinate.
* Locate individual plots randomly, using a randomization procedure in a GIS to specify the coordinates of each plot.

### Timing of sampling

In addition to random location of the plots, it is critical that plot sampling is undertaken at the same time of year each time repeat sampling at permanent sample plots is undertaken. The goal is to sample the plots under, to the greatest degree possible, the same ecological and treatment conditions with each repeat sampling. Thus the day and month of establishment of permanent sample plots, and the ecological conditions existing at that time, must be recorded. Future samples at these plots should be established within 15 days of the same day and month in the year in which the plots are resampled, unless significantly changed ecological or treatment conditions (for instance a very late spring, late tillage, etc.) mandate a greater gap between the initial sampling date and a specific later repeat sampling date.

### Step 4.2 Soil Sampling Plot Design

The sampling plot is designed to allow for very efficient installation and permanent field marking to ensure it can be relocated and re-sampled in the future. The design is shaped in circular form, that typically fits natural patch sizes in the field better then square or rectangular or linear plot shapes. Figure 1 shows the dimensions and provides an example of how individual soil sampling locations within the plot could be randomly sampled using several different soil sampling methods, and resampled over time to accommodate resampling. The plot is designed to accommodate at least three soil sampling methods: the use of soil core sampling technologies and extraction; the use of dug soil pits where rocks, roots and unconsolidated substrate conditions do not allow core sampling to be effective; and, the use of newer insitu methods that involve inserting direct reading probes into the soil without necessarily having to extract soil samples en-mass as the core and pits methods, and correlations between these methods.

The plot design physically separates these three intervention methods and by following the instruction below, no interaction, bias, or violation of statistical independence occurs.

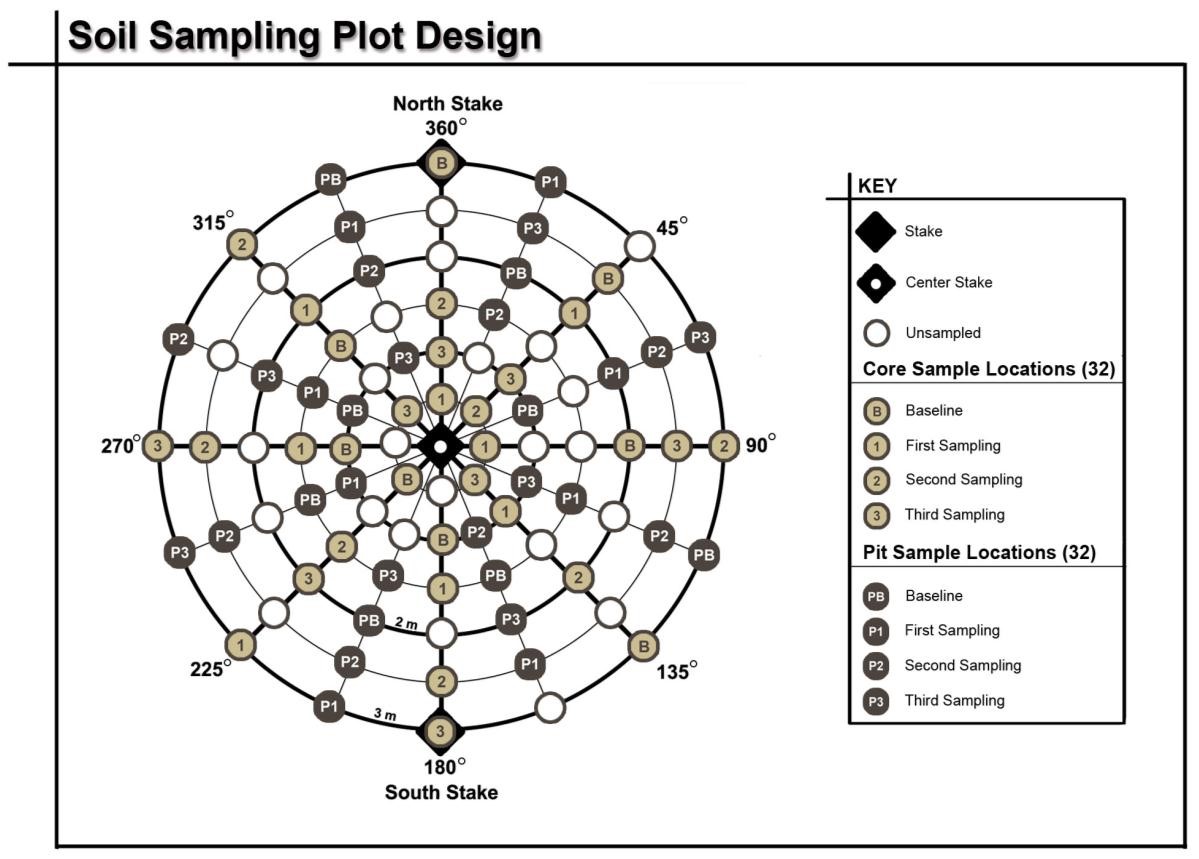


Figure 1. Layout of core and soil pit sampling site marking. Permanent plots centers and key radial end points allows easy metal detector relocation, re-measuring and gives statistical robustness and power.

### Step 4.3 Initial Plot Establishment and Subsequent Relocations Steps

**Step 4.3a** **Plot location:** Using a handheld GPS with sub-meter accuracy, walk to the coordinates determined during Step 4.1, which locates the plot center. Achieving sub-meter accuracy may require use of control points (points with a known location). During initial plot establishment, install re-locatable marker. This marker may consist of:

* A 15-20 cm long by 0.25-0.50 cm diameter steel or iron rebar stake or 20-30 cm wire stake flag pins inserted into the soil at the plot center, and in the other locations as indicated in the sample plot figure. The rebar or wire stake pin must be completely buried by a minimum of 3-5 cm of soil to prevent discovery and damage to this marker, or injury to wildlife, livestock or humans, and vehicle tires in the future. This method should only be used where management does not include use of implements which could displace the center marker, or be damaged by the marker
* A power line marker or similar detectable marker buried 30 to 50 cm deep (at least 1.5 times the depth of expected disturbance) at the plot center where management disturbance (tillage or other activities) is possible.
* A surface marker outside the plot area along a fence line or other location where disturbance is unlikely. In this case the distance and direction from the marker to the plot center must be accurately determined and recorded.

If the sample plot location falls in an area of exposed bedrock or impermeable parent material (for instance compacted till) or an impermeable man made material (for instance a road surface), determine whether the area is representative (more than 5% of the stratum area is composed of areas of this type). If the area is representative, the sample plot must not be moved. On the other hand, if the area is anomalous (less than 5% of the stratum area is composed of areas of this type), the entire sample plot may be systematically relocated by moving the plot to a randomly located point, unless the project scenario includes activities which are expected to rebuild soil systems in locations of exposed bedrock or impermeable parent material.

When previously established plots are being re-sampled, a metal detector may be required to locate the exact location of the plot center and north stakes. Where an erosion measurement point has also been established, both the plot center stake and the erosion monitoring point must be found, to ensure that the correct stake is identified as the plot center.

**Step 4.3b Plot layout**: Laying out the plot in the field may be undertaken using the following steps:

**Step 4.3b1** Mark the center point of the plot using the techniques described in Step 4.3a below.

**Step 4.3b2** Secure one end of a precut and graduated tape or rope at the center stake and pull the tape or rope taught and strait on a magnetic north bearing (bearing of 360)

**Step 4.3b3** Sight back over the tape or rope and ensure the back bearing registers a 180 degree magnetic north bearing. Adjust position as necessary to achieve this alignment of the tape/rope over the 180 degree back bearing.

**Step 4.3b4** Establish the direct north stake point with another pounded rebar stake or buried marker, installed as in Step 4.3a. For relocating a formerly established north stake, use the same GPS and metal detector technique for relocating the metal center stakes.

**Step 4.3b5** Establish the direct south point, located 3 meters south of the center point. Use the pre-measured tape or rope that is pulled to align the center of the length over the center stake and north end over the north stake. Flag the south end location with a temporary wire stake flag.

**Step 4.3b6** Establish the 6 meter long radial that is magnetically aligned with the east (90 deg) to west (270 deg) compass bearings. Stretch the rope or tape taught between endpoint stake temporary flags and center the tape over the center plot stake.

**Step 4.3b7** Establish the 6 meter long northeast (45 deg) to southwest (225 deg) tape or rope using the same method as in Step 4.2e.

**Step 4.3b8** Establish the 6 meter long northwest (315 degrees) to southeast (135 deg) tape or rope using the same method as in Step 4.2e.

**Step 4.3c** **Sampling point relocation** The goal is to ensure that previous sampled points within a plot are not re-sampled on subsequent resampling events. Prior to commencing with plot installation, randomly select pit or core sample locations (an example is shown in Figure 1) for each planned sampling event. Five, to as many as eight, of the points within the plot should be sampled during each sampling event. If the planned number of sampling events requires more sample points than those shown in the diagram, the plot may be expanded or the number of sample points sampled per event can be reduced to a minimum of three. An additional point sampled at each sampling event will be a soil pit. If obstacles, such as large surficial rocks or trees, which have soil underneath them within the sampling depth, prevent collecting samples at designated points, it may be necessary to move sampling locations. For core samples, adjust by moving the center of the core sample in 5 centimeter increments north of prior designated point(s). For pits, randomly choose another of the pit sampling locations, shown on Figure 1. If, on the other hand, an outcrop of bedrock or compacted material, or an embedded boulder (a large rock extending down to below the sampling depth) prevents collecting samples, the sampling point should not be moved, and the soil depth should be recorded as zero. Note that results from such sampling points must only be used in determining the average soil depth used in the calculations, and must not be used in the determination of average soil carbon percentage within the stratum.

**Step 4.3d Plot maintenance and records:** To ensure independence among samples from the first and all subsequent soil sampling events, no extracted soil materials must be deposited on the surface of the sample plot. The soils removed from pits will be used to backfill the pits and backfill or cap the boreholes. During the sampling process the project proponent must ensure that even small amounts of soils or other materials are not accidently dropped from the core or shovel used during sampling onto other areas of the sampling plot.

Denote on the sample plot diagram and record which sampling points and pit locations have been sampled during each sampling period. Accurate recording of which sample points are actually sampled is necessary as points sampled in the field may be different than the a-priori randomly selected sample points. Also, record when adjustments are made to respond to rock, bedrock, tree roots, not being able to find a sample point, or where changes in the sample point justify it as atypical or modified from other representative conditions in the sample plot.

Sampling methods must remain constant from one measurement round to the next.

**Step 4.3e Recording of soil layers**: At each sampling location, use either a sampling probe (a 1 to 8 cm diameter stainless steel probe with a functional length equal to or greater than the sampling depth) or a shovel to extract or expose soil layer samples for observations, recording the depth of each soil layer. At minimum these must include depths of surficial humus layers, “A” and “B” layers, interbedded layers, hydrological indicators such as mottling or gleying, and depth to the “C” layer. Additionally, any other soil information commonly used to determine soil types in national, regional or local soil classification systems should be collected. For each soil layer record the texture, colours (using a Munsel standard colour book), hydrological indicators (e.g. mottles, reduction indicators), and the thickness. The sequence of soil layers must be determined down to the sampling depth.

Soil sampling will be undertaken using either core probe samples (may include power auger and core samples, etc.), or soil pits. Use soil pits if roots, rock or unconsolidated substrates do not allow the sampling and collection of soil samples using core probe samples, as defined above.

**Step 4.3f Sampling soil carbon and bulk density:** From each sample point, collect a separate soil sample from each soil layer. Place each sample in a plastic bag which is labeled with sample plot sample point and layer identification code, to ensure identification for later processing and analysis.

Additionally, for each soil layer, collect a single composite soil sample that combines equal amounts of soil from each of the three sampling points within the plot. Alternatively, the composite sample for each plot can also be created by removing from each previously bagged core or pit substrates sample, a homogenized subsample which is then added to the composite sample bag and labeled as above to record the plot number, composited strata layer, and date. The composite and individual collected samples will be submitted to analytical laboratories for carbon and other analyses.

To allow determination of the bulk density of each layer of soil, collect a known volume of undisturbed soil from each sampled soil layer within the plot. Typically this can be achieved by pressing a soil can of known volume into an undisturbed section of soil from the intact sides of a pit, or cutting a section of known length out of a sufficiently large diameter core sample and bagging it. Where soils are cohesive, this may require carving a block of soil to precisely fit the sampling can. Bulk density canisters need to be of a size appropriate to capture inherent soil structure variance such as found where aggregated soil structures are found. Typically, a canister of 74-150 cubic centimeters is adequate for this purpose. Regardless of soil sampling method, the goal is to extract intact sections that have not been compressed or altered by the sampling methodology and equipment, that are representative of each of the soil strata present, and to ensure that bulk density sampling, used to determine carbon content by soil volume, is accurate.

**Step 4.3g Sampling coarse fragment content:** Where soils contain a significant component of *coarse fragments* (rock and cemented fragments larger than the screen size used in the laboratory prior to testing for soil carbon), the percentage of the soil composed of these fragments must be determined. One or both of the two methods given below should be used, depending on the size of the *coarse fragments* present:

### Small coarse fragments (Coarse fragments between 2mm and 10 mm in diameter, and therefore small enough to be included in the bulk density sample)

Where soil contains significant amounts of coarse fragments small enough to be included in the bulk density sample, the mass of the bulk density sample without the coarse fragments must be determined. This is done either in an eligible laboratory, or in the field, by screening the bulk density samples. Determination must be done separately for each soil layer.

### Large coarse fragments (Coarse fragments greater than 10 mm in diameter, and therefore too large to be included in the bulk density sample, but not too large to move)

Where soils contain significant amounts of coarse fragments too large to be contained in the bulk density sample, the percentage of the volume of the soil composed of these fragments must be determined. Typically this can be accomplished by excavating soil from a hole of known volume, containing a minimum of 25 kg of soil, screening out the coarse fragments meeting the specified size criteria, and determining the volume of these fragments using water displacement, conversion from weight to volume, or other techniques. This determination must be done separately for each soil layer. Note that these coarse fragments do not include large embedded boulders, which are accounted as described in Step 4.3b above.

### Step 5 Soil Sample Preparation and Laboratory Procedures

**Goal**: Completion of laboratory tests on soil properties.

**Product**: Accurate soil test results for measured soil properties.

**Method:**

### Step 5.1 Soil Sample Preparation

All samples need to be inventoried, labeled and packaged for shipping to ensure they are accurately recorded, and to ready the samples for laboratory analyses and archival preservation.

***Sample preparation.*** If the nitrogen content of the soils is to be tested, freeze soil samples prior to delivery of the samples to a laboratory. Specimens need to be delivered to the testing laboratory immediately or at least as fast as possible once sample labeling is completed and the soil sample is recorded in a tracking system. Soil sample drying is done by the laboratory to which the samples are to be delivered, using repeated weighing to achieve and demonstrate constant dried weight is achieved which is required for bulk density precision. Note that for some soils (some clays and volcanic soils in particular) achieving a constant weight may be difficult without high heat drying. In that case, a subset of the soil sample should be weighed, dried at high heat, and weighed again, and a correction factor for the soil density derived from this subsample. Details of this procedure are found in the manual: *Soil Survey Laboratory Methods Manual* (USDA 2004).

***Bulk Density.*** Measure the volume and initial wet and achieved final dry weight of the soils in the bulk density samples, and calculate the weight per unit volume based on these measurements. Screen the bulk density sample and determine the weight per unit volume of soil without the *coarse fragments*, as discussed in Step 4.3f above.

***Chain of Custody.*** For fresh or dried samples, submit a chain of custody form to the soil testing laboratory and ensure that the laboratory maintains the chain of custody records.

***QA/QC.*** The chosen soil testing laboratory must have a rigorous Quality Assurance program that meets or exceeds the US EPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detention limits for each constituent analyzed.

***Sample Archiving***. Samples must be large enough to permit future re-testing. To do so, make arrangements with the chosen laboratory to create archival quantity samples. Archived samples must be either completely dried or frozen, to prevent ongoing biological activity from changing soil carbon densities, or their chemistry. Archived samples of all soil samples submitted should be kept at minimum until completion of the next verification. Additionally, a sufficient number of samples from each sampling event to cover the range of conditions expected to be found in the project area under the project scenario should be stored for the life of the project to allow recalibration of results where future advances in soil testing methods may result in potential loss of comparability between results.

### Step 5.2 Laboratory Procedures

All laboratory procedures must follow the methods given in the most current version of the following manual: *Soil Survey Laboratory Methods Manual,* Soil Survey Investigations Report No. 42, Version 4.0 by the USDA Natural Resources Conservation Service, dated November 2004, or a standard of equivalent rigor.

#### Precision Levels

Two forms of testing error may occur at the lab: systematic and specific. The laboratory must meet the following precision levels:

***Systematic Error.*** Systematic error occurs when instrument miscalibration or other problems result in consistent errors in results. Laboratories must demonstrate that in testing of standardized control samples the difference between the sample results and the known carbon content is not greater than +/- 2% of the known carbon content of the control sample.

***Specific Error.*** Specific error occurs when testing of a given sample results in incorrect results, even though no systematic error is present. In order to test for specific errors, split a homogenized sample and submit both split samples labeled differently. Compare test results between the two subsamples and determine the specific error. Differences between split samples must not be greater than 10% of the greater of the two reported results.

As a standard procedure, for projects with a small number of samples (≤50) at least 10% of the samples must be split and independently tested and compared. For projects with larger sample sets (>100), no less than 10 samples must be split and independently tested.

### Step 6 Analytical Laboratory Data Checking and Calculation

**Goal**: Accurate calculation of soil parameters based on laboratory results.

**Product**: Laboratory results which are quality checked, and calculated soil parameters based on the laboratory results.

**Method:**

### Step 6.1 Data checking

Evaluate if all reported values are within the expected data ranges based on prior analysis and reports. Identify any that appear aberrant. Review the quality of the variances from the split blind samples. If results do not indicate that the estimated soil carbon levels of the split samples are from the same population or soil setting (10% variance with a 90% confidence interval). Retesting of soil samples may be required. These tests must be undertaken for soils collected from the same soil type, slope, vegetation cover typing, based on the *stratification* described in the introduction and Step 1 of this module.

Conclude which points appear to be outlier data points with what appear to be significantly skewed or divergent reported data outside the range of similarity to other data point results. If these are present in the data set, reasons for the variance must be determined based on the plot characteristics. Based on this analysis, one of the following options must be followed:

* If no significant differences in plot characteristics are found, compared with other plots in the stratum, the results must be retained and used in calculations for the stratum.
* If significant differences in plot characteristics are found, and these characteristics resemble the characteristics of another stratum, the plot may be re-assigned to the other stratum.
* If significant and highly anomalous differences in plot characteristics are found, and it can be demonstrated that these anomalous characteristics are unique and do not exist elsewhere within the stratum, the plot may be deleted.

Request retesting by the laboratory of archived samples if some results appear to be aberrant and cannot be explained.

### Step 6.2 Adjustment of variables

As discussed in Step 3, certain soil processes (compaction, accrual, erosion, deposition, etc.) have the potential to result in errors in estimation of the changes in atmospheric carbon resulting from soil carbon fluxes. The following methods must be used to reduce the risk of errors in estimation when using the equations given above. Note that in some cases more than one of these soil altering processes may be present, and more than one method may be needed to reduce the risk of errors in calculation of soil carbon. In such cases, the project proponent must justify the suite of methods used, and demonstrate that the methods will not to result in an overestimation of the reductions in atmospheric carbon resulting from the project.

### Step 6.2a Changes in soil density

*A black and white logo

AI-generated content may be incorrect.*Changes in soil density may occur as a result of compaction or decompaction. For each sampling point where the sampling depth was not restricted by bedrock or a cemented layer, and for each sampling time after the initial sampling, if the soil density (bulk density) changes by more than 5% from the first sampling event to subsequent sampling events, the calculated depth for that plot must be adjusted such that the factor *ts* is the same for each sampling period, where *ts* is calculated as follows:

(5.1)

|  |  |  |
| --- | --- | --- |
| *l*  Where  *ts* *l*  *sdl*  sdensl | =  =  =  = | The total mass of soil in a 1 cm2 column, g/cm3  The soil layers found in the plot  The depth (thickness) of soil layer x above the calculated depth, cm  The bulk density of soil layer x, g/cm3 |

Example:

For the project, a calculated depth is 30 cm has been chosen. During the first sampling the soil is found to consist of two layers, as shown in table 6.3.1 below

Sampling time 1

Thickness above the

Soil layer calculated depth, cm Bulk Density, g/cm3

|  |  |
| --- | --- |
| 20 | 1.1 |
| 10 | 1.2 |

A

B

*ts*=34

Table 6.2.1 T=1 sampling

During the second sampling, the soil is found to be as follows:

Sampling time 2

Thickness above the

Soil layer calculated depth, cm Bulk Density, g/cm3

|  |  |
| --- | --- |
| 22 | 1 |
| 10 | 1.1 |

A B

*ts* =30.8

Table 6.2.2 T=2 sampling

Because the soil bulk density has changed, the total amount of soil above the calculated depth has changed – in this case it has gone down, due to decompaction. The calculated depth must therefore be adjusted, to ensure that calculations are based on the same amount of soil. In this case, the new calculated depth will be 32.9, as shown in the table 6.3.3.

Sampling time 2, adjusted

Thickness above the

Soil layer calculated depth, cm Bulk Density, g/cm3

|  |  |
| --- | --- |
| 22 | 1 |
| 10.9 | 1.1 |

A

B

*ts* =34.0

Table 6.2.3 T=2 sampling, with calculated depth adjusted, such that *ts* for time 2 = *ts* for time 1

Note that if the new calculated depth extends below the bottom of the lowest soil layer calculated at time T=1 (in this case stratum B), the thickness of that soil layer must be the thickness found in the field, and data from the next soil layer down must be used for the remaining depth. For this reason it is critical to ensure that sampling in the field includes a substantial depth below the expected calculated depth as decompaction could potentially occur.

### Step 6.2b Changes in the amount of soil present

Changes in the amount of soil present may occur through processes of erosion or deposition, or through the planned addition of soil amendments such as char. Where such processes are predictable (for instance, where regular alluvial deposition of soils occurs within a floodplain), their amount and location must be projected when preparing the baseline carbon estimates for the project. Also, where such processes are predictable, project proponents must ensure that plots are distributed to be reasonably representative of the range of erosion and deposition processes within the site. For instance, if a rolling agricultural site sees regular movements of soil from steeper areas of the topography to valleys and benches during intense rainstorms, plots must be located to representatively capture both the steeper erosion areas and the flatter deposition zones. In some cases these two areas may be separate strata, in which case plots will automatically be representative. In other cases, however, the impact of other processes and factors on soil carbon may be so much greater than this movement of soil that both the steeper and flatter areas fall within a single stratum, and the plots within that stratum must to be representative of that diversity.

***Soil Amendment***: Where changes in the amount of soil result from the addition of amendments, no changes in sampling depths or calculation depths should be undertaken to adjust for the amendment. However, note that amendment may result in changes in bulk density which may result in adjustments to the calculated depth as described in Step 6.3a above.

***Erosion*:** Erosion events occurring within the project areamay consist of small specific events (for instance, a small slippage), or may consist of large areas of sheet erosion or other comparable processes. Where plots within a stratum fall in small, unrepresentative (<1/(number of plots times 2)% of the stratum area) erosion areas, the plots must be dropped. On the other hand, where erosion covers a larger portion of the stratum area, plots must be retained. Project proponents may choose either to continue to include the erosion area within the existing stratum, if the erosion impacts were relatively small, or to create a new stratum consisting of the eroded area, where the impacts of the erosion event were greater. Creation of a new stratum may lead to a requirement to install new permanent sample plots to ensure that the new strata meet statistical requirements.

Where changes in soil depth result from erosion, the amount and form of carbon released to the atmosphere as a result of the erosion process may vary widely, depending on the nature to the erosion event, the degree of separation of the carbon fraction of the soil from the mineral fraction of the soil during the erosion event, and the nature of the location where the carbon fraction of the eroded soil is eventually deposited. Due to these uncertainties, no changes to the calculated or sampled depths may be made after the erosion event, unless the event takes place in an area with a bedrock or cemented layer which restricts the sampling depth, in which case erosion may by default reduce the calculated and sampled depths.

The one exception to this rule will occur in the case that the sampling subsequent to the erosion event finds a new soil layer, high in carbonates, or consisting of a buried surface soil horizon, at the bottom of the sample. In such cases the actual carbon percentage of this layer must not be used, and the carbon content of the layer must be calculated using the carbon percentage found in the layer immediately above it.

***Deposition:*** As with erosion, deposition may occur in small localized areas (for instance, at the tail of a slide) or across a broader area, as in the case of wide alluvial deposition zones. The same rules must be followed for elimination or retention of a plot falling into a deposition area, and restratification where necessary, as those given above for erosion.

Where changes in soil depth result from deposition, total sampling and calculation depths must not be changed. Where sampling and calculation depths were restricted by bedrock or cemented layers, subsequent sampling and calculations must only be undertaken to the depths previously used, even though more soil is now present.

Note that both deposition and erosion may result in changes in the nature and sequence of soil layers within the sample.

### Step 6.2c Apparent changes in the amount of soil present where bedrock or cemented layers are present

Where soil sampling depths are restricted by bedrock or cemented layers, the sampling depth may change from point to point within a plot, even though no actual change in the amount of soil present, and no compaction or decompaction, has occurred. For instance, the depth to bedrock of the three sampling points at a given plot might be as follows:

Changes in values between first

Total Sampling depths, cm and second sampling time

First sampling Second Erosion or

Sample time sampling time deposition Bulk density

|  |  |  |  |
| --- | --- | --- | --- |
| 28 | 29 | No | No |
| 24 | 26 | No | No |
| 27 | 30 | No | No |

1

2

3

Total 79 85

Table 6.2.4 Changes in sampling depths between two sampling times, due to different depths to bedrock at different points within the plot**.**

If significantchanges in bulk density have occurred, or significantdeposition or erosion is found, adjustments to the calculated depth must be made using the methods given in Steps 6.3a or 6.3b, as applicable. However, if, as in the example given, no such significantchanges are found, then the layer depths and total calculation depth used in the calculations for the first sampling time must also be used in the calculations for the second sampling time as well, in place of the actual measurements from the second sampling time, to eliminate false attributions of changes in total carbon resulting from different depths to bedrock or cemented layers across the plot.

### Step 6.3 Accounting for soil carbon added as amendments

Some treatments, such as the addition of lime, char or manure to the soil, may directly add carbon to the soil. Adjustments to calculations of soil carbon may be required, depending on the source of the amendment.

### Step 6.3a Amendments sourced within the project area

Amendments are considered to be sourced within the project area under the following conditions:

* For amendments other than manure, at least 95% of the biomass carbon must be sourced from within the project area, and must come from an accounted carbon pool. Thus for instance if char is derived from living biomass grown within the project area, and living biomass pools are accounted, the amendment is considered to be sourced within the project area. This will be the case even if the biomass is processed into char outside of the project area. On the other hand, if lime is sourced from within the physical boundaries of the project area, but comes from rock deposits or other sources which are not accounted pools, it cannot be considered to be sourced from the project area for the purposes of carbon accounting.
* For manure, the feedstock used for the animals must be at least 80% sourced within the project area. The percentage of feedstock sourced within the project area will be measured based on annual calorific value available to the animals. It is not required that the animals themselves be kept within the project area.

Where amendments meet the criteria given above, no adjustment to the soil carbon estimates is required. However, the following qualifications on emissions should be noted:

* If the processing of biomass into char, compost, or similar materials, or the processing of lime occurs within the project are*a*, all emissions from the processing must be accounted as project emissions.
* If the processing of biomass into char, compost or similar materials, or the processing of lime occurs outside of the project area, the emissions must be accounted as leakage.
* If the animals from which the manure is sourced are kept within the project area, their emissions will be accounted as required in this methodology. If the animals from which the manure is sourced are kept outside of the project area, their emissions must be accounted as leakage. Where only a portion of the manure from these animals is used as soil amendment within the project area, the emissions may be prorated based on the percentage of the total manure used within the project area.

**Step 6.3b Amendments sourced outside of the project area:**

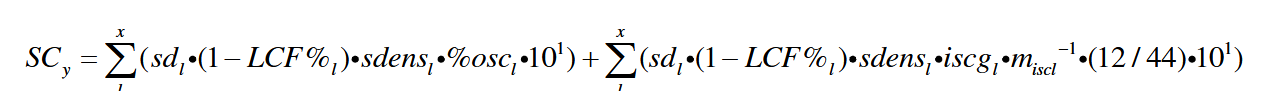
Where carboniferous amendments are sourced from biological or non-biological sources outside the project area, a deduction must be made from the calculated soil carbon as follows:

* Where amendments are long lived, meaning that at least 80% of the carbon in the amendment tends to remain in the soil for more than 10 years – for instance, where the amendment is char – 100% of the carbon content of the amendment must be deducted from the calculation of soil carbon in Step 6.6.
* Where amendments are not “long lived” – for instance, where the amendment is manure, 80% of the carbon in amendment must be deducted from the calculation of soil carbon in Step 6.6, unless the project proponent can show scientific evidence demonstrating that less than 80% of the carbon derived from the amendment will remain in the soil 10 years after application, in which case a percentage of the carbon contained in the amendment may be deducted. The percentage used must be conservative, based on the available scientific literature.

In either case the deduction need not be made if it can be shown that at least 95% of carbon in the amendment comes from a source within the project area of another carbon project, and the source biomass pool is being accounted in that project. In this case, if the emissions from processing the amendment are not being accounted within the other carbon project, they must be accounted as leakage within this project.

**Step 6.4 Data Calculation: Total soil carbon**:

Subject to the guidance given in step 6.3, the following equation is used to calculate soil carbon per unit area.



(5.2)

Where

*SCy* = Total measured soil carbon per square meter at plot y, kg/m2

*x* = The number of soil layers measured *l* = Soil layers

|  |  |  |
| --- | --- | --- |
| *sdl* | = | The average depth (thickness) of soil layer x found in the sampling points within the plot, cm |
| *LCF%* | = | The % of soil volume composed of large coarse fragments, % |
| *sdensl* | = | The average oven dry bulk density of soil layer x after removal of coarse fragments, found in the sampling points within the plot, g/cm3 |
| *%oscl* | = | The average mass of organic soil carbon in layer x, as a percentage of the total mass of the samples, as measured in the laboratory, % |
| iscgl | = | The average mass of CO2 emitted from the soil samples during acid testing, g |
| miscl | = | The average mass of the samples tested using acid testing , g. |
| 12/44 | = | Conversion from CO2 to C |

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AI-generated content may be incorrect.Note: The depth *sdx* of the bottom-most measured soil layer is the thickness of that layer from the top of the layer to the calculated depth, or to bedrock or a cemented layer, whichever is less.

Note: The laboratory will often provide the term as a single value, percentage inorganic carbon.

Note: As discussed in the introduction, where changes in inorganic carbon are not expected to be significant, only organic carbon may be accounted.

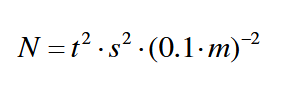
Note: %oscl and iscgl will be the average value determined from the samples submitted to the laboratory for that plot. If one or more sampling points within the plot have no soil (exposed bedrock, for instance), no sample will be submitted, and the sampling point will not be included when calculating %oscl and iscgl.

### Step 6.5 Statistical Calculations

Calculate the standard deviation and the confidence interval for total carbon for each stratum. If soils contain significantamounts of inorganic soil carbon, and these amounts are not expected to change, statistical calculations must be undertaken based on the amount of organic soil carbon only, to avoid the masking effects of the large and static pool of inorganic soil carbon. In these cases only organic soil carbon may be accounted and reported, and the portion of the equation accounting inorganic carbon must be set to 0.

Where the confidence interval exceeds +/- 10% with 90% confidence, project proponents may undertake one of three actions:

1. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-stratification should be considered, as discussed in module *TRS-1 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals must be recalculated for the new strata. Re-stratification will require the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards, unless the project proponent elects to use option c for that stratum.
2. Increase the number of plots: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further plots. An estimate of the required number of further plots must be calculated, using the equation below (3), and further plots installed, located systematically or randomly.

 (5.3)

|  |  |  |
| --- | --- | --- |
| Where |  |  |
| *N* | = | Total number of plots expected to be required |
| *t* | = | Student t-test 0.90 value for n-1, n being the number of plots already established |
| *s* | = | Standard deviation for the existing plot values |
| *m* | = | Mean value of the variable from the existing plots |

1. Recalculate SoilCs

In some cases, due to project size or other factors, installing enough plots to meet the required confidence interval may not be economically viable. In these cases, and provided that project proponents install a minimum of 10 plots per stratum, project proponents may proceed with data gathered to a lower confidence interval. However, project proponents must recalculate SoilCs (from Step 6.6 below) as follows:

* 1. Where sampling is undertaken prior to project start date to determine the baseline.

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AI-generated content may be incorrect. (5.4)

Where:

*SoilCs*= Total soil carbon in stratum s, t *ci* = The calculated confidence interval at 90% confidence

* 1. Where sampling is undertaken after project commencement to determine soil carbon under the project scenario.

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AI-generated content may be incorrect. (5.5)

Where

*SoilCs*= Total soil carbon in stratum s, t *ci* = The calculated confidence interval at 90% confidence

### Step 6.6 Calculating the total accounted soil carbon for the stratum

A number of symbols on a white background

AI-generated content may be incorrect.The total accounted soil carbon for the stratum will be calculated using the following equation.

(5.6)

Where

*SoilCs*= Total soil carbon in stratum s, t

|  |  |  |
| --- | --- | --- |
| *ys* | = | The plots in stratum s |
| *#ys* | = | The number of plots in stratum s, dimensionless |
| *SCy* | = | The average soil C per m2 in plot y, kg/m2 |
| *As* | = | The area of stratum s, m2 |
| *10-3* | = | Conversion from kg to t |
| *ACs,t* | = | Carbon added to the soil as accounted amendments in stratum s to time t, t |

Note: See Step 6.3 to determine the value of the variable *ACy*. The carbon in all accounted amendments applied from the start of the project to the time of the calculation must be deducted.

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *ts* |
| Data unit: | *g/cm3* |
| Description: | Mass of soil |
| Source of data: | Calculated from sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | The total mass of soil in a 1 cm2 column to the calculated depth |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *l* |
| Data unit: | # |
| Description: | The soil layers found in the plot |
| Source of data: | Plot data |
| Justification of choice of data or description of measurement methods and procedures applied: | The various soil layers found in the plot, distinguished on the basis of texture, density, soil organic carbon content, or other features |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *sdx* |
| Data unit: | *cm* |
| Description: | Thickness of the soil layer |
| Source of data: | Plot measurement |
| Justification of choice of data or description of measurement methods and procedures applied: | The depth (thickness) of soil layer x above the calculated depth, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *sdensx* |
| Data unit: | *g/cm3* |
| Description: | Soil bulk density |
| Source of data: | Measured from field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | The bulk density of soil layer x, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *E* |
| Data unit: | % of the mean |
| Description: | Allowable error |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | e.g. ±10% of the mean |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *t* |
| Data unit: | Dimensionless |
| Description: | t value |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Student’s t-test value for the confidence level (e.g. 90%) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *L* |
| Data unit: | # |
| Description: | Amount of strata |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Total of number of strata types in the area to be sampled |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *sh* |
| Data unit: | Depending on estimated variable |
| Description: | Estimated standard deviation |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | estimated standard deviation of stratum h |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data** **Unit / Parameter:** | *Ch* |
| Data unit: | $ |
| Description: | Cost to select and sample a plot in the stratum |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Cost to select and sample a plot in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *N* |
| Data unit: | # |
| Description: | Total Number of samples |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of sample units (all strata) N=∑Nh |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Nh* |
| Data unit: | # |
| Description: | Number of samples per stratum |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of sample units for stratum h calculated by dividing the area of stratum h by area of each plot. |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Wh* |
| Data unit: | Dimensionless |
| Description: | Proportion of samples in stratum of total amount of samples |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Nh/N |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *SCy* |
| Data unit: | kg/m2 |
| Description: | Amount of carbon per m2 |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Total measured soil carbon per square meter at plot y to a specified depth |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *x* |
| Data unit: | # |
| Description: | Number of soil layers |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Tthe number of soil layers measured |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | ***l*** |
| Data unit: | # |
| Description: | Soil layers |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil layer(s) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *sdl* |
| Data unit: | cm |
| Description: | Thickness of soil layer |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | The depth (thickness) of soil layer l |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *LCF%* |
| Data unit: | % |
| Description: | % of large coarse fragments |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | The percentage of the soil volume composed of large coarse fragments |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *sdensl* |
| Data unit: | g/cm³ |
| Description: | The average bulk density of soil layer l |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: | The bulk density of soil layer l, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *%oscl* |
| Data unit: | % |
| Description: | Percentage of organic soil carbon in layer l |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | The percentage of organic soil carbon in layer l, as measured in the laboratory from soil samples collected at the plots |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *iscgl* |
| Data unit: | Tonnes |
| Description: | Mass of inorganic soil carbon emitted as CO2 |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | The mass of inorganic soil carbon emitted as CO2 during acid testing in the laboratory |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *miscl* |
| Data unit: | Kg |
| Description: | Mass of the sample tested using acid testing |
| Source of data: | Laboratory measurement of tested sample |
| Justification of choice of data or description of measurement methods and procedures applied: | The mass of the sample tested using acid testing in layer l |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *12/44* |
| Data unit: | Dimensionless |
| Description: | Conversion from CO2 to C |
| Source of data: | Periodic table |
| Justification of choice of data or description of measurement methods and procedures applied: | Conversion from CO2 to C |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *ACs,t* |
| Data unit: | Tonnes |
| Description: | Carbon in soil amendments |
| Source of data: | Accounting of carbon containing soil amendments applied |
| Justification of choice of data or description of measurement methods and procedures applied: | Carbon added to the soil as accounted amendments to time t |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *#ys* |
| Data unit: | # |
| Description: | Number of plots |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of plots in stratum s |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *As* |
| Data unit: | m2 |
| Description: | Stratum area |
| Source of data: | Measured using GPS or other means of similar accuracy |
| Justification of choice of data or description of measurement methods and procedures applied: | The area of stratum s, |
| Any comment: |  |

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## DOCUMENT HISTORY

|  |  |  |
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| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-4

ESTIMATION OF CARBON STOCKS IN LIVING PLANT BIOMASS

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## Table of Contents

[1 SOURCES 2](#_Toc53278)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc53279)

[3 DEFINITIONS 2](#_Toc53280)

[4 APPLICABILITY CONDITIONS 3](#_Toc53281)

[5 PROCEDURES 3](#_Toc53282)

[6 PARAMETERS 17](#_Toc53283)

[7 REFERENCES AND OTHER INFORMATION 25](#_Toc53284)

# 1 SOURCES

Adapted from CDM AR-AM0001 (now in consolidated methodology CDM AR-ACM0002), CDM ARAM0004 Reforestation or afforestation of land currently under agricultural use*.*

CDM A/R Methodological Tool *Calculation of the number of sample plots for measurements within A/R CDM project activities* (Version 02)

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides the methods to be used to estimate the required number of living plant biomass plots in each stratum, design and establish the plots, and check the statistical rigor of the results.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Biomass Expansion Factor (BEF):** | The ratio of the total aboveground *biomass* to the measured portion of the biomass of a plant |
| **Ex-ante:** | Before the fact. Projection of values or conditions in the future. |
| **Ex-post:** | After the fact. Estimation of values or conditions in the present or past. |
| **Permanent Sample**  **Plots:** | Plot being measured more than once and provide high quality, long-term, local data on growth of the existing forest for a variety of species and sites. |
| **Project Area:** | The area of land on which the project proponent will undertake project activities. |
| **Significant:** | A pool or source is significant if it does not meet the criteria for being deemed de minimis. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. |
| **Stratum (plural strata):** | An area of land within which the value of a variable, and the processes leading to change in that variable, are relatively homogenous. |
| **Woody Biomass:** | Biomass which exists primarily in the form of lignified tissues, such as that of shrubs and trees. Typically accounting of woody biomass includes the non woody parts (leaves, etc.) of plants which contain woody biomass. |
| **Wood Density:** | The mass per unit volume of the dry wood of a given species. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

### Introduction

Living vegetation may be found in a wide number of forms and distributions, including woody and nonwoody, and evenly distributed, clumped, or scattered. A number of different techniques may be used to sample living vegetation, depending on the nature of the type and distribution. This module provides methods for three separate but related approaches to determining total living plant biomass in a stratum. Several basic variables are determined through sampling:

For trees and large woody vegetation

* The number of trees per stratum by species or species group.
* The size of the trees.

For small woody vegetation and non-woody vegetation

* The amount of aboveground biomass in a specified area.

Based on these variables, total biomass will be estimated.

Separate approaches are therefore given for sampling and calculation of biomass for trees and large woody vegetation, and for small woody and non-woody vegetation.

**PART A: Trees and large woody vegetation**

### Step 1: Stratification and determination of distribution

Stratification of the area within the project area, and where required within the leakage belt or reference region, must be undertaken using the methods specified in module *TRS-1 Methods to Determine Stratification*. During stratification, particular attention should be given to the species and spatial distribution, and ecological and management dynamics of the trees and large woody species.

**Step 2: Determination of the number, size and distribution of woody species.**

Based on the preliminary stratification, one of three basic approaches must be used to estimate the number and size of large woody species individuals:

***1) Census from remote sensing, plus correlation with ground sampling***

### Determining the number of individuals

This approach is particularly suited to sampling woody individuals where those individuals are openly distributed, or scattered, and where the individuals are mostly large enough to be detected using remote sensing and automated classification techniques. This approach has the advantage of allowing a complete (100%) census, or estimation based on censusing of large portions of an area, to determine the number of individuals present. This approach is also particularly suitable where remote sensing techniques based on historical images will be used in module *TRS-7 Estimation of Woody Biomass Harvesting and Utilization* to forecast future trajectories of woody species populations.

Conducting a census from remote sensing typically requires the use of high resolution satellite based images (Quickbird or similar), or, preferably, aerial systems providing sub-meter resolution.

Automated techniques to identify woody species individuals and quantify the number of individuals present can be implemented using a number of remote sensing and GIS software packages. Specific packages are not identified in this methodology, since this is a rapidly developing field. However, the software package chosen must have been subject to peer review for uses similar to those being applied in the project, and must be recognized as a leading software package for this purpose (For example: ECognition, ArcGIS). Depending on the nature of the data, and the species present on the site, it may also be possible to determine the species mix from the remote sensing data. Where this is not possible, the species mix must be determined using ground sampling.

Where remote sensing techniques are used, but a 100% census is not undertaken, selection of areas to assess must be systematic and unbiased.

For QA/QC purposes, error estimations of interpretations of remote sensing images must be made using other data – ideally ground sampling. Ground sampling must be undertaken such that trees identified from remote sensing data can be located on the ground, and errors detected, such as:

* Trees which have been missed in the interpretation of the remote sensing data.
* Trees which have been identified in the remote sensing data, but which do not exist on the ground – for instance, erroneous interpretation of shadow areas as trees.
* Trees identified from the remote sensing data which are actually tree clumps on the ground.

The maximum allowable error (difference between the number of trees detected from remote sensing and the actual number found on the ground) must not exceed 10%.

In some cases, remote sensing may be efficient to detect individuals over a certain size, but may miss smaller individuals. In such a case, ground sampling methods must be used to inventory the smaller woody individuals, and a check between ground samples and remote census must be undertaken to ensure that neither systematic double counting nor systematic failure to detect individuals of a given size class is occurring.

### Determining the size and species of individuals

Where remote sensing techniques are used to determine the number of individuals, one of the following two techniques must be used to determine the size and species of individuals:

a. Correlation to detectable canopy size classes and spectral signatures.

Where remote sensing imagery has high enough resolution to permit automated classification of canopy size and spectral signatures for individuals of woody species, it may be possible to determine a function which relates canopy size and detected species to biomass in individuals. Developing such a function requires the following steps:

1. Division of the detectable canopy sizes into canopy size classes. The number of classes will depend on the size variation of individuals in the woody species layer, and the resolution of the imagery, but a maximum of five or six classes must be defined. The goal of identifying canopy size classes is to reduce the variance, and therefore the number of samples required to achieve acceptable statistical significance in correlating canopy size to biomass. Selection of both detectable canopy size classes, as well as spectral signatures, as discussed in the step below, must be undertaken using existing peer reviewed industry standard methods. Specific details are not given here, as this is a rapidly changing field.
2. Determination of the spectral signatures for individual species or groups of similar species. Note that the ground sampling undertaken in the next step may determine that the correlation between canopy size and biomass extends across multiple species, or may in some cases apply with acceptable accuracy across all trees present on the site. Thus the final analysis may be able to lump species together even though those species are identifiable using their spectral signature.
3. Ground sampling of specific individuals, identifiable from the remote sensing, and covering the range of identifiable canopy size classes, and identified species. Note that in this case establishment of plots containing more than 1 tree is not required, since numbers are determined from the remote sensing, and ground sampling is for determination of biomass and species identification only.
4. Calculation of above and below ground biomass for each sampled individual, using one of the techniques given in Step 3 below.
5. Analysis of statistical variance in the biomass of the sampled individuals in each canopy size class. In general the error of the mean must be not more than +/- 10% at a 90% confidence level.
6. If good statistical correlation based on the analysis of statistical variance is found between canopy size class and biomass, a function can be developed, and woody species biomass can be calculated from the remote sensing images.

Using this technique, biomass will be calculated using the following equation:

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AI-generated content may be incorrect. *y x*

(6.1)

*sg c*

Where:

Bws  = Total large woody biomassin stratum s, tonnes

*bws*  = Total woody biomass in the stratum of individuals too small to detect by remote sensing, calculated using the techniques given in section 3 below, tonnes

*sg =* The species or species groups *y =* The number of species or species groups *c*  = The canopy size classes, non-dimensional *x* = The number of canopy size classes

*t#sc* = The number of individuals of a given species or species group and a given canopy size class in the *stratum*, non-dimensional

*bwsc* = The average woody biomass per individual in a given canopy size class and species or species group

*As =* The area of the stratum

*Ac =* The area of the portion of the stratum which was censused using remote sensing

As noted above, the woody species layer may also contain some individuals below a cutoff for detection by remote sensing. Biomass for these size classes will be estimated using the plot methods given below.

While this approach may require substantial sampling effort to achieve the required statistical relevance, it has the advantage of allowing direct estimation of woody species biomass from historical images. This may significantly aid in the development of woody species biomass projections for use in estimation of long lived wood products where relevant.

b. Without canopy size class detection

Where reliable correlations (measured using statistical variance of the samples taken within the canopy size class, as discussed in Step 2.1.a.1) between canopy size class and biomass are not expected or where canopy size cannot be reliably detected from remote sensing, the same techniques as those given above must be used, except that only one canopy size class, encompassing all detectable individuals, will be used. In this case a large number of individuals may need to be sampled to reach the required statistical precision, since individuals of all sizes will be sampled.

#### 2) Area from remote sensing, plus sampling

This approach uses remote sensing to identify areas of woody species, combined with ground sampling to determine the woody species density within those areas. It is particularly suited to clumpy distributions of woody species, where the clumps are too frequent to be efficiently stratified out as a separate stratum.

In this case remote sensing resources are used to delineate in a GIS the areas covered in woody species, and ground sampling is then undertaken to determine the density and biomass of individuals within these areas, using the ground sampling methods discussed below, but with sampling confined to the areas identified from the remote sensing.

#### 3) Ground Sampling

Ground sampling is the most commonly used approach to estimating the number, species and size of trees present in an area. Ground sampling is preferred for high density woody species stands, whether continuous or clumped, and for areas dominated by shrubs and small trees which are difficult to detect remotely.

When ground based sampling is used for sampling of woody biomass, permanent sampling plots should be used for sampling over time to measure and monitor above and below ground biomass. Permanent sample plots are generally regarded as statistically efficient in estimating changes in forest biomass and carbon stocks because there is typically a high covariance between observations at successive sampling events. However, the project proponent must ensure that the plots are treated in the same way as other lands within the project area (e.g., during site and soil preparation, weeding, fertilization, irrigation, or thinning). Ideally, staff involved in management activities should not be aware of the location of monitoring plots. Where local markers are used, these should not be visible.

Plots must be established using the following guidance:

### Plot size and shape

* Trees: Plot size and design for the measurement of trees will vary depending on the nature of the stand. If consisting of multiple age or size classes of trees, with different distributions for each class, nested plots may be used. For single age stands, a single plot size should be sufficient. The size of plots depends on the density of trees, in general between 100 m2 for dense stands and 1000 m2 for open stands. However, larger plots capturing more trees may be more efficient in cases where access is difficult and variability high, since fewer plots may be required.
* Non-tree woody vegetation: Plot area for larger non-tree woody vegetation will also depend on the distribution of the non-tree vegetation. For relatively dense, uniform layers, a plot as small as 4 m2 may be used. For strata with growing trees, the plots should be sub-plots of plots for measuring trees;
* Plots may be any shape, as long as shape is predetermined to avoid bias, and the plot boundaries can be reliably relocated for subsequent re-measurement. In general, for smaller plots circular plots are often more efficient, while for larger plots square or rectangular plots are preferred.

### Number of Plots

The number of plots depends on species, density and size variability within the stratum, accuracy requirements and monitoring interval. In this methodology the total sum of samples and the sample size is determined using the approved CDM A/R Methodological Tool *Calculation of the number of sample plots for measurements within A/R CDM project activities* (AR-AM Tool 03 - Version 02 or later version).

It is possible to reasonably modify the sample size after the first monitoring event based on the actual variation of the carbon stock changes found.

### Plot Location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more “convenient” positions), the permanent sample plots must be located either systematically with a random start, or randomly using a randomization algorithm in a GIS system. Location of plots can be accomplished with the help of a GPS in the field. The geographical position (GPS coordinate), administrative location, stratum and sub-stratum series number of each plots must be recorded and archived.

Sampling plots should be as proportionally distributed across geographic sites as possible For example, if one *stratum* consists of three geographically separated sites, then the project proponent could:

* Divide the total stratum area by the number of plots, resulting in the average area per plot;
* Divide the area of each site by this average area per plot, and assign the integer part of the result to this site. For example, if the division results in 6.3 plots, then 6 plots are assigned to this site and 0.3 plots are carried over to the next site, and so on.

### Step 3: Calculation of biomass – Trees

The amount of aboveground biomass and belowground biomass in each measured tree can be estimated using either of two methods, the Allometric Equations method or the Biomass Expansion Factors (BEF) method.

#### Allometric method

**Step a:** Measure the diameter at breast height (DBH, at 1.3 m above ground), and preferably the height, of all the trees in the permanent sample plotsabove a minimum DBH. The minimum DBH varies depending on tree species and climate, for instance, the minimum DBH may be as small as 2.5 cm in arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly (GPG-LULUCF, 2003).

When first measured all trees must be tagged to permit the tracking of individual trees in plots through time.

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AI-generated content may be incorrect.**Step b:** Choosing or establishing and applying appropriate allometric equations.

(6.2)

Where:

BABs = Aboveground biomass of tree in stratum s, tonnes tree-1

*fi*(*DBH,H*) = An allometric equation linking aboveground biomass (tonnes tree-1) to diameter at breast height (DBH) and possibly tree height (H).

Allometric equations produce estimates of biomass in kg per tree.

Preferably, the allometric equations used are locally-derived, species-specific, and peer reviewed.

When such Allometric equations are not available, Allometric equations developed from a biome-wide database, such as those in Annex 4.A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF (2003), may be used. Where such equations are used, project proponents must verify the equation’s applicability to the project. Verification must be undertaken by destructively harvesting no less than 5 trees of the species or species group to which the equation is to be applied within the *project area* but outside the sample plots. The biomass of these trees must be measured, and compared to the results derived from the selected equation. If the biomass measured from the harvested trees is not more than 10% less than that predicted by the Allometric equation, it can be assumed the selected equation is suitable for the project.

If this is not the case, it is recommended to develop local allometric equations for the project. In order to develop the equations, a sample of trees, representing different size classes, is destructively harvested, and the total dry biomass of each tree is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as the DBH and total height (see Chapter 4.3 in GPG LULUCF (2003)).

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AI-generated content may be incorrect.**Step c:** Estimate belowground biomass using root to-shoot ratios and aboveground carbon stock.

(6.3)

Where:

BBBs = Belowground biomass of tree in stratum s, tonnes

BABs = Aboveground biomass of tree in stratum s, tonnes

R = Root-to-shoot ratio

Note that in some cases the allometric equations utilized in step b may provide direct estimates of both above and below ground biomass, in which case Step c will be unnecessary. Where a root-to-shoot ratio is used, it must be selected based on the same criteria as those discussed in step C of the BEF method, below.

#### BEF Method

**Step a:**Measure the diameter at breast height (DBH, at 1.3 m above ground), and preferably the height, of all the trees in the permanent sample plots above a minimum DBH. The minimum DBH varies depending on tree species and climate, for instance, the minimum DBH may be as small as 2.5 cm in arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly (GPG-LULUCF, 2003).

**Step b:** Estimate the volume of the commercial component of trees based on locally derived equations. It is also possible to combine step a above and this step if field instruments are used (e.g. relascope) that measure volume of each tree directly.

**Step c:** Choosing BEF and root-to-shoot ratio: The BEF and root-to-shoot ratio vary with local environmental conditions, species and age of trees, and the volume of the commercial component of trees. These parameters can be determined by either developing a local regression equation or selecting from national inventory, Annex 3A.1 Table 3A.1.10 of GPG LULUCF (2003), or from published sources. If a significantamount of effort is required to develop local BEFs and root-to-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local Allometric equations as described in the Allometric method above (refers to Chapter 4.3 in GPG LULUCF, 2003). If that is not possible either, national species specific defaults for BEF and R can be used. Since both BEF and the root-to-shoot ratio are age dependent, it is desirable to use agedependent equations. Stem wood volume can be very small in young stands and BEF can be very large, while for old stands BEF is usually significantly smaller. Therefore using average BEF value may result in significanterrors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent BEFs (but for very young trees, multiplying a small number for stem wood with a large number for the BEF can result in significanterror).

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AI-generated content may be incorrect.**Step d:** Converting the volume of the commercial component of trees into aboveground biomass and belowground biomass via basic wood density, BEF, root-to-shoot ratio and carbon fraction, given by[[9]](#footnote-11):

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(6.5)

Where:

BABs = Aboveground biomass, tonnes

BBBs = Belowground biomass, tonnes

V = Merchantable volume, m3

D = Wood density of the species, in dry weight per unit volume, tonnes d.m.m-3 merchantable volume.

BEF = *Biomass* expansion factor for conversion of biomass of merchantable volume to aboveground biomass, dimensionless.

R = Root-to-shoot ratio, dimensionless

### Step 4: Calculation of total woody biomass per plot

Total tree biomass per plot is the sum of all above and below ground biomass in all trees within the plot. Where nested plots or plots of different sizes for different types of woody biomass have been used, each different plot size must be calculated separately.

### Step 5: Testing statistical confidence

Calculations to test the statistical confidence of the mean must be carried out on the total above and below ground large woody biomass per plot for each stratum. As described above, where nested or different sized plots are used, separate calculations must be done for each size or type of plot, or statistical calculations may be carried out on a per unit area basis (usually by conversion of individual plot results to per ha results prior to statistical analysis). Confidence interval must not be greater than 10%, at a 90% confidence level, for each stratum.

Where the confidence interval exceeds +/- 10% with 90% confidence, project proponents may undertake one of three actions:

1. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-*stratification* can be considered, as discussed in module *TRS-1 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals must be recalculated for the new *strata*. Re-stratification will require the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards unless option C is chosen for that stratum.

1. Increase the number of plots: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further plots. An estimate of the required number of further plots should be calculated, using the equation below (3), and further plots installed, located systematically or randomly.

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(6.6)

Where

N = Total number of plots expected to be required

t = Student t-test 0.90 value for n-1, n being the number of plots already established s = Standard deviation for the existing plot values m = Mean value of the variable from the existing plots

1. Recalculate *Bws*

In some cases, due to project size or other factors, installing enough plots to meet the required confidence interval may not be economically viable. In these cases, and provided that project proponents install a minimum of 10 plots per stratum, project proponents may proceed with data gathered to a lower confidence interval. However, project proponents must recalculate *Bwi* (from step 6 below) as follows:

1. Where sampling is undertaken prior to project commencement to determine the baseline

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## (6.7)

Where:

*Bws* = Total large woody biomass in stratum s, tonnes *ci* = The calculated confidence interval at 90% confidence

2. Where sampling is undertaken after project commencement to determine biomass carbon under the project scenario

## *A black and white image of a number AI-generated content may be incorrect.* (6.8)

Where

*Bws* = Total large woody biomass in stratum s, tonnes

*ci* = The calculated confidence interval at 90% confidence

### Step 6: Calculation of total large woody biomass

The total large woody biomass for each stratum is calculated using the following equation:

*z*

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AI-generated content may be incorrect.* (6.9)

|  |  |  |
| --- | --- | --- |
| Where: | |  |
| *Bws* | = | Total large woody biomass in stratum s, tonnes |
| *As* | = | The area of the stratum s, hectares |
| *p* | = | The different plot sizes or types |
| *z* | = | The number of plot sizes or types |
| *Bwp* | = | The average woody biomass per plot in a given plot size or type p, tonnes |
| *sp* | *=* | The size of the given plot type p, m2 |

### PART B: Small woody and non-woody vegetation

For smaller woody and non-woody vegetation a destructive sampling method must be used. The steps in sampling and calculating biomass for smaller woody and non woody biomass are:

### Step 1: Stratification and determination of distribution

Stratification of the area within the project area, and where required within the leakage belt or reference region, must be undertaken using the methods given in module *TRS-1 Methods to Determine Stratification*. During stratification, particular attention must be given to the species and spatial distribution, and ecological and management dynamics of the smaller woody and non-woody vegetation.

### Step 2: Sampling

**Step a**: **Plot Size**. Destructive sampling entails the collection of all aboveground material within the plot. As such, plots are typically relatively small, to avoid the necessity of collecting large amounts of material. Square plots of 1m by 1m are acceptable where the material is relatively evenly distributed at the individual plant level. Where more heterogeneous distributions are found, larger plots may be considered.

**Step b: Plot Location.** Plots must be systematically or randomly distributed throughout the *stratum*. Where large woody plants and trees are also being sampled using the methods given above, plots must be located in areas where remote sensing or ground sampling allows the individual trees and large shrubs to be clearly identified and excluded from the destructive sampling, to ensure that double counting, or missing of some biomass, does not occur. Where destructive sampling is being undertaken in combination with permanent sample plots, the location of the destructive sampling sub-plot within the permanent sample plot must be recorded, and a new location for the destructive sampling subplot must be chosen for each subsequent re-measurement of the permanent sample plot.

Where a significant proportion of the small woody and non-woody material being sampled is distributed in clumps or patches, notes must be taken identifying whether the plot falls in a clump or patch or in an area between clumps or patches. If the area is highly heterogeneous due to clumpiness, it may be necessary to summarize the results separately for the clumps and the areas between the clumps, in order to reduce the number of plots required to meet statistical precision levels.

If plots within clumps and outside clumps are summarized separately, the amount of area within a stratum consisting of clumps or patches must be determined. This may be done in one of two ways:

* From remote sensing, if the clumps or patches are clearly identifiable on remote sensing images.
* Using a line intersect survey. A line intersect survey consists of lines systematically laid out and covering the stratum evenly and without bias. Each line is walked, and notes are kept on the sections of the line which fall within clumps or patches. The percentage of the total line length falling within a clump or patch is then the estimated percentage of the area lying in clumps or patches.

**Step c: Installation of plots and measurement of biomass**. Within the designated plot area, all biomass which has not been accounted in a survey of trees and large woody biomass is cut and collected. This biomass is then weighed, oven dried, and weighed again, to give both green and dry weights. Ideally the biomass is oven dried, to achieve “bone dry” conditions. However, drying in direct sun may also be used. In case biomass samples are weighed after sun drying, small representative subsamples need to be taken from the larger sample, weighed, oven dried as described above, and weighed again to determine the level of residual moisture in the weighed sample. The dry weights of the samples must then be adjusted accordingly, to provide an estimated oven dry weight of the biomass per plot.

### Step 3: Testing statistical confidence

Calculations to test the statistical confidence of the mean must be carried out on the total above ground biomass per plot. The error of the mean must not be greater than 10%, at a 90% confidence level.

Where the confidence interval exceeds +/- 10% with 90% confidence, project proponents may undertake one of three actions:

1. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-stratification should be considered, as discussed in module *TRS-1 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals must be recalculated for the new strata. Re-stratification will require the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards, unless option c is chosen for that stratum.

1. Increase the number of plots: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further plots. An estimate of the required number of further plots must be calculated, using the equation below (3), and further plots installed, located systematically or randomly.

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(6.10)

Where

N = Total number of plots expected to be required

t = Student t-test 0.90 value for n-1, n being the number of plots already established s = Standard deviation for the existing plot values m = Mean value of the variable from the existing plots

1. Recalculate *Bsms*

In some cases, due to project size or other factors, installing enough plots to meet the required confidence interval may not be economically viable. In these cases, and provided that project proponents install a minimum of 10 plots per stratum, project proponents may proceed with data gathered to a lower confidence interval. However, project proponents must recalculate *Bsmi* (from step 4 below) as follows:

i. Where sampling is undertaken prior to project commencement to determine the baseline

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Where:

*Bsms* =Total biomass of small woody and non-woody living vegetation in *stratum* s, t *ci* = The calculated confidence interval at 90% confidence

ii. Where sampling is undertaken after project commencement to determine biomass carbon under the project scenario

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## (6.12)

Where

*Bsms* =Total biomass of small woody and non-woody living vegetation in *stratum* s, t *ci* = The calculated confidence interval at 90% confidence

### Step 4: Calculation of Total Small Woody and Non-woody Biomass

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AI-generated content may be incorrect.*Total small woody and non-woody biomass per stratum is then calculated using the following equation:

(6.13)

Where:

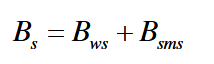
|  |  |  |
| --- | --- | --- |
| *Bsms* | = | Total biomass of small woody and non-woody living vegetation in *stratum* s, t |
| *sbp* | *=* | Small biomass plots |
| *w* | *=* | Number of small biomass plots |
| *bs* | *=* | Biomass of the collected small woody and non-woody vegetation in each plot, kg |
| *Asbp* | = | Area of the small biomass plot, m2 |
| *As* | *=* | The area of the stratum, hectares |
| *Rs* | *=* | A root-to-shoot ratio for the small woody and non-woody biomass, Dimensionless |

Notes:

1. Where distribution of biomass has been clumpy or patchy, it may be necessary to undertake the calculation twice, once for the clumps or patches, and once for the areas between the clumps or patches, and then to sum the results. In this case, the area *A* will be the area of the patches, or the area between the patches, as relevant.
2. Determination of the root-to-shoot ratio *Rs* for highly heterogeneous species mixes may be complex. Where different species sampled have different root-to-shoot ratios, the most conservative (smallest) root-to-shoot ratio must be used for the calculations. In many cases, root-to-shoot ratios can be found in the scientific literature. However, consideration should also be given to undertaking excavation and weighing of dry root and top weight for species where good root-to-shoot ratios are not found in the literature[[10]](#footnote-12), and where the proponent has reason to believe that the species in question may vary significantly from other species. Since undertaking this measurement may be extremely difficult, the proponent may alternately propose a root-to-shoot ratio for the species which is demonstrably conservative (for instance, which is lower than the known root-to-shoot ratio for the most comparable species).

### PART C: Total Living Biomass

Total living biomass in a stratum is the sum of the tree and large woody biomass, as calculated in Part A, and the small woody and non-woody biomass, as calculated in Part B:

** (6.14)

Where:

|  |  |  |
| --- | --- | --- |
| *Bs* | = | Total biomass in stratum s, t |
| *Bws* | = | Total large woody biomass, t |
| *Bsms* | = | Total biomass of small woody and non-woody living vegetation, t |

# 6 PARAMETERS

|  |  |
| --- | --- |
| Data Unit / Parameter: | *bwsc* |
| Data unit: | Tonnes |
| Description: | The averagewoody biomassper individual per species in a given canopy size class |
| Source of data: | Estimation from ground sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | Single tree sampling of individuals identified and randomly chosen from remote sensing, using standard field mensuration methods given in the methodology |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *C* |
| Data unit: | Dimensionless |
| Description: | Canopy size classes |
| Source of data: | Remote sensing imagery |
| Justification of choice of data or description of measurement methods and procedures applied: | Determined by dividing the range of canopy sizes detectable from remote sensing imagery into groupings based on the distribution of canopy sizes found. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *X* |
| Data unit: | *#* |
| Description: | The number of canopy size classes |
| Source of data: | Remote sensing imagery |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of canopy size classes *c* determined using the methods described for that variable |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Sg* |
| Data unit: | Dimensionless |
| Description: | The individual tree species or species groups |
| Source of data: | Determined by the proponent based on techniques described below. |
| Justification of choice of data or description of measurement methods and procedures applied: | Combination of remote sensing and ground surveys to identify species or species groups which are distinguishable in remote sensed imagery using spectral signature, form, etc. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Y* |
| Data unit: | *#* |
| Description: | The number of species or species groups distinguished |
| Source of data: | Remote sensing and ground truthing |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of canopy size classes *s* determined using the methods described for that variable |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *t#sc* |
| Data unit: | Dimensionless |
| Description: | The number of individuals of a given species or species group and a given canopy size class in the stratum, no dimension |
| Source of data: | Remote sensing imagery |
| Justification of choice of data or description of measurement methods and procedures applied: | Count of individuals from remote sensing imagery |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bws* |
| Data unit: | *T*onnes |
| Description: | Total woody biomass in the stratum of individuals too small to detect by remote sensing, |
| Source of data: | Estimated using field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated using the techniques given in section C of this methodology |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bws* |
| Data unit: | *T* |
| Description: | Total large woody biomass per stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated using equation 6.1 |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *As* |
| Data unit: | Hectares |
| Description: | Area of the stratum |
| Source of data: | Measured |
| Justification of choice of data or description of measurement methods and procedures applied: | Measured from ground surveys or cartography |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Ac* |
| Data unit: | m2 |
| Description: | Area of the portion of the stratum censused |
| Source of data: | Measured |
| Justification of choice of data or description of measurement methods and procedures applied: | Measured from cartography |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *BABs* |
| Data unit: | tonnes tree-1 |
| Description: | Aboveground biomass of tree in stratum s |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated using an allometric equation linking a measurable (usually diameter breast height) to total tree biomass |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *BBBs* |
| Data unit: | Tonnes |
| Description: | Belowground biomass of tree in stratum s |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated using a root-to-shoot ratio |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *R* |
| Data unit: | Dimensionless |
| Description: | Root-to-shoot ratio for the given species or species group and size/age class |
| Source of data: | Existing data or measurement |
| Justification of choice of data or description of measurement methods and procedures applied: | Derived from existing data where appropriate data exists. In some cases some destructive sampling may be required to determine this ratio. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *V* |
| Data unit: | m3 |
| Description: | Merchantable volume |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated from field measurements |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *D* |
| Data unit: | Tonnes d.m.m-3 merchantable volume. |
| Description: | Wood density for the species |
| Source of data: | Existing data |
| Justification of choice of data or description of measurement methods and procedures applied: | Derived from existing data for wood density of the species. Preferably from local research. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *BEF* |
| Data unit: | Dimensionless |
| Description: | Biomass expansion factor applicable to the species or species group |
| Source of data: | Existing research or destructive sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | These parameters can be determined by either developing a local regression equation or selecting from national inventory, Annex 3A.1 Table 3A.1.10 of GPG LULUCF, or from published sources. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *P* |
| Data unit: | *#* |
| Description: | The different plot sizes or types |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The different plot sizes or types used to measure biomass of different size classes, determined by the proponent to meet statistical requirements |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Z* |
| Data unit: | *#* |
| Description: | The number of plot sizes or types *p* |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Count of the number of plot sizes or types used for large woody vegetation |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bwi* |
| Data unit: | *Tonnes* |
| Description: | The average woody biomass per plot in a given plot size or type i |
| Source of data: | Plot measurements |
| Justification of choice of data or description of measurement methods and procedures applied: | Estimation from plot measurements using methods given in the methodology |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *sp* |
| Data unit: | m2 |
| Description: | The size of the given plot type p |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The size of the different plot sizes or types used to measure biomass of different size classes is determined by the proponent to meet statistical requirements |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bsms* |
| Data unit: | *T* |
| Description: | Estimated total biomass of small woody and nonwoody living vegetation in stratum s |
| Source of data: | Calculated estimate from field sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | Estimate calculated from field sampling using the equations given in the methodology |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *sbp* |
| Data unit: | *#* |
| Description: | Small biomass plots |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of plots determined by statistical requirements |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *W* |
| Data unit: | *#* |
| Description: | Number of small biomass plots |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of plots determined by statistical requirements |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *bs* |
| Data unit: | kg |
| Description: | biomass of the collected small woody and nonwoody vegetation in each plot |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Dry weight of biomass collected from each plot |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Asbp* |
| Data unit: | m2 |
| Description: | Area of the small biomass plot |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Area of the plot used is determined by the small vegetation density in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Rs* |
| Data unit: | Dimensionless |
| Description: | Root-to-shoot ratio for the small woody and nonwoody biomass |
| Source of data: | Existing data or destructive field sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | Determination of the root-to-shoot ratio *Rs* for highly heterogeneous species mixes may be complex. Where different species sampled have different root-to-shoot ratios, the most conservative (smallest) root-to-shoot ratio must be used for the calculations. In many cases, root-to-shoot ratios can be found in the scientific literature. However, consideration should also be given to undertaking excavation and weighing of dry root and top weight for species where good root-to-shoot ratios are not found in the literature, and where the project proponent has reason to believe that the species in question may vary significantly from other species. Since undertaking this measurement may be extremely difficult, the project proponent may alternately propose a root-to-shoot ratio for the species which is demonstrably conservative (for instance, which is lower than the known root-to-shoot ratio for the most comparable species). |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bi* |
| Data unit: | t |
| Description: | Total biomass in stratum s |
| Source of data: | Summed from estimated data |
| Justification of choice of data or description of measurement methods and procedures applied: | Summed from estimations of total large woody biomass and total small woody and non-woody biomass in the stratum |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

CDM AR-AM0001 (now in consolidated methodology CDM AR-ACM0002) AR-ACM0002: http://cdm.unfccc.int/UserManagement/FileStorage/CDM\_ACM2B3FZAKHOM5TPX6WC19NDFFPT4J3Y

E (visited 18-05-2010).

CDM AR-AM0004 Reforestation or afforestation of land currently under agricultural use. ARAM 004 http://cdm.unfccc.int/UserManagement/FileStorage/KYBDLQFMI6R20X58OGH3Z71N9TSU4A (visited 18-05-2010).

IPCC, 2003, GPG-LULUCF (<http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html>, lastvisited 14-09-2011)

CDM A/R Methodological Tool *Calculation of the number of sample plots for measurements within A/R*

*CDM project activities* (AR-AM Tool 03 - Version 02 or later version)

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-5

ESTIMATION OF CARBON STOCKS IN THE LITTER POOL

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 2](#_Toc28979)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc28980)

[3 DEFINITIONS 2](#_Toc28981)

[4 APPLICABILITY CONDITIONS 2](#_Toc28982)

[5 PROCEDURES 2](#_Toc28983)

[6 PARAMETERS 9](#_Toc28984)

[7 REFERENCES AND OTHER INFORMATION 12](#_Toc28985)

# 1 SOURCES

None

# 2 SUMMARY DESCRIPTION OF THE MODULE

The module consists of methods for sampling litter pools for continuous and point source litter types, estimating the total litter biomass within an area and calculating the carbon content of the liter pool.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Litter:** | See *VCS Program Definitions.* |
| **Stratification:** | The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

Litter for the purposes of this methodology includes all dead organic matter lying on the surface and less than 4 cm in diameter. Organic matter greater than 4 cm in diameter will be accounted using the module *TRS-6 Estimation of carbon stocks in the dead wood pool.*

Three types of litter distribution can occur:

* Dispersed – Litter is present throughout the area more or less evenly. For instance, litter derived from grasses and forbs will often be dispersed throughout the area where the grass is growing.
* Accumulated – Litter has been accumulated in specific locations, typically by the action of wind or water, or by human action.
* Point source – Litter originates from a point source which is not uniformly distributed throughout the area, such as a tree in a savanna ecosystem. Point source litter is distributed around the source, and may not occur at all in gaps where no source is present.

Measurement of litter accumulations must be undertaken differently for each type of litter. Prior to collection of litter data, the area must be stratified to reflect differences in biological community or physical conditions which may lead to different amounts or patterns of litter accumulation. Where more than one type of litter is found in a single stratum (for instance in the case of a savanna with scattered trees, where both dispersed and point source litter may be found), more than one form of measurement and estimation method should be used in a single stratum.

Therefore the total litter biomass for a stratum will be

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Where:

|  |  |  |
| --- | --- | --- |
| *Bls* | = | Litter biomass per stratum, t |
| *Bld* | = | Dispersed litter biomass per stratum, t |
| *Bla* | = | Accumulated litter biomass per stratum, t |
| *Blp* | = | Point source litter biomass per stratum, t |

The types of litter are accounted as follows:

### 1) Dispersed

Dispersed litter types must be sampled using area collection plots. Plots must be distributed randomly or systematically, and may be associated with other types of plots such as soil plots. Because litter does vary seasonally, it is critical that repeated litter plots be put into place on approximately the same date each time samples are taken to minimize seasonal variability.

Typically, a one square meter frame is laid on the ground, and all the litter within the frame is collected. Collected material must not include living biomass. Litter collected must include all dead biomass, both standing and fallen. Where very small or very large amounts of litter are found, other sizes of plots may be used. The collected litter is oven dried, and weighed. Within a given stratum, sufficient plots must be installed to meet the statistical requirements identified in the section on statistics below. Litter biomass from dispersed litter types is calculated using the following equation:

## A black and white text AI-generated content may be incorrect. (7.2)

Where:

*Bld* = Dispersed litter biomass per stratum, t

*A* = Stratum area, hectares

*Lw* = Total dry litter weight of the collected litter, kg

*n* = Number of litter plots, #

*PSl* = Plot size of the litter plot, m2

### 2) Accumulated

Accumulated litter must be measured using the same methods and equations as dispersed litter, with the following differences:

 The percentage of the area of the stratum covered in accumulated litter must be estimated. Depending on the type of litter accumulation it may be possible using very high resolution

(sub centimeter multi-spectral) remote sensing to directly detect the litter accumulations, or to

map conditions such as lee pockets where litter accumulates. Where remote sensing cannot detect litter accumulations, the percentage of the stratum area covered in accumulated litter must be estimated by walking a systematic or random path across the stratum, and maintaining line intersect notes to note the beginning and ending points each time the path crosses a litter accumulation. If the line intersect method is used, the percentage of the line crossing accumulated litter will be the percentage of the area accounted as having accumulated area, and the area covered by accumulated litter is therefore estimated as:

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(7.3)

Where:

*Aal* = The area covered with accumulated litter, hectares

*LI%al* = The percentage of the traverse line which covers accumulated litter areas, non-dimensional

*A* = Stratum area, hectares

 The same sample plots as those used for dispersed litter must be used. However, plots must be located only in areas of accumulated litter. As above, sufficient plots must be installed to meet the statistical requirements identified in the section on statistics below.

Accumulated litter is therefore calculated using the following equation:

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Where:

|  |  |  |
| --- | --- | --- |
| *Bla* | = | Accumulated litter biomass per stratum, t |
| *Aal* | = | Area within the stratum covered with accumulated litter, hectares |
| *Lw* | = | Total dry litter weight of the collected litter, kg |
| *n* | = | Number of litter plots, # |
| *PSl* | = | Plot size of the litter plot, m2 |

### 3) Point source

Point source litter will typically be found surrounding the litter source, such as a tree. Litter accumulations will often vary in depth from the center to the perimeter of the area under and around the source. Thus measurements must be undertaken using the following steps:

1. Determine the minimum size of sources with litter accumulations.

In many cases, below a certain minimum size trees or other sources will have no measurable litter accumulation. If this is true, determine whether inventory data for the sources will allow sources below the minimum size to be typed out and removed from the inventory or not.

1. Estimate the number of sources per hectare.

Point source litter arises from discrete, non-continuous sources such as scattered trees. The number of sources per hectare must be estimated using any of the survey techniques noted in module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*. Depending on the outcome of Step 1, the estimate of the number of sources may exclude sources that are below a certain minimum size.

1. Sample the litter depths.

Point source litter is typically distributed under and/or around the source, with litter depths varying with the distance from the source.

The following steps must be used to sample the litter*:*

* 1. Select sample sources. Sources must be selected systematically or randomly, and may, for example, be selected based on a selection rule at plots established for other measurements. If sources below a minimum size have been eliminated from the inventory in Step 2, these sources must not be selected. Based on field experience, amounts of point source litter vary widely from point to point. Thus project proponents are not expected to meet statistical precision requirements for this type of litter. However, project proponents are required to demonstrate that the points sources sample are representative of the range of sizes of sources. A minimum of 30 point sources must be sampled for each stratum where point source litter exists.

* 1. Lay out a sample line. The sample line must run in a preselected direction (for instance a cardinal point) from the center of the source.

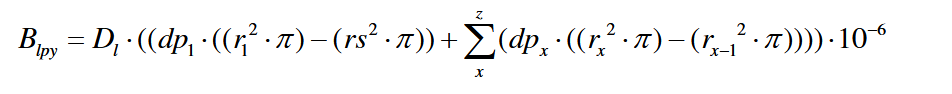
* 1. Measure the litter depth. Litter depth must be measured at a series of preselected distances from the center. The first distance from the center will always be the radius of the stem of the point source. Within this radius the litter depth will be zero. Beyond that point distances shall be systematic and predetermined (measurements taken every 30 cm, for example). Measurements must be continued outward from the point source until litter from this source makes up less than 50% of the litter found. Measured litter depths must not include any layer of litter from other sources which may lie on top of the litter from the source in question, but will include such litter embedded within the litter layer

1. Determine the litter density.

Litter density must be determined by sampling a constant volume of undisturbed litter – for instance by pressing a can of known volume upside down into the litter to fill the can. The resulting litter samples must be totally dried, and weighed to determine a weight per unit volume.

1. Calculate the total point source litter biomass at each sampled point source based on calculation of the volume of litter in a series of rings beginning at the source and moving outward, using the following equation:

*z*

** (7.5)

*x*

Where:

*Blpy* = Total point source litter biomass at sampled point source *y*, t

*Dl* = Density of the litter, g/cm3

*dpx* = The depth of the litter layer at measurement point x (point 1 being closest to the center of the source), averaged across all of the samples, cm

*rx* = The distance from the center to measurement point x, cm

*rs =* The radius of the stem of the litter source. If there is no stem, rs=0

*x =* The number of the measurement point, with point 1 being the closest to the center of the source

*z =* The number of the measurement point farthest from the center

Statistical calculations for point source litter must be calculated based on *Blpy* following the guidance given in the section on statistical calculations below:

1. Calculate the total point source litter in the stratum

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## (7.6)

*y*

Where:

*Blp* = Total point source litter biomass in the stratum, t

*Blpy* = Total point source litter biomass at sampled point source *y*, t

*z* = The number of sample points

*A* = Area of the stratum, ha

*PS# =* The number of accounted point sources per hectare

### Statistical Calculations

Calculate the standard deviation and the confidence interval for total carbon for each type of litter independently. Where the confidence interval exceeds +/- 10% with 90% confidence for any of the litter types within the stratum, project proponents must undertake one or more of the following three actions:

1. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-stratification can be considered, as discussed in module *TRS-1 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals must be recalculated for the new strata. Re-stratification requires the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards, unless the project proponent chooses to utilize option c, below, for that stratum.

1. Increase the number of plots: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further plots. An estimate of the required number of further plots must be calculated, using the equation below (3), and further plots installed, located systematically or randomly.

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(7.7)

Where

N = Total number of plots expected to be required

t = Student t-test 0.90 value for n-1, n being the number of plots already established

s = Standard deviation for the existing plot values

m = Mean value of the variable from the existing plots

1. Recalculate the value of *Bld*, *Bla* or *Blp*: In some cases, due to project size or other factors, installing enough plots to meet the required confidence interval for a given litter type may not be economically viable. In these cases, project proponents can proceed with data gathered to a lower confidence interval if an appropriate confidence deduction is taken.

Increasing uncertainty caused by the reduced confidence interval will result in a deduction as determined by the *VCS Standard v3.4* or most recent version. The project proponents must recalculate the total estimated biomass for the relevant litter type (*Bl, Bla* or *Blp*) as follows:

1. Where sampling is undertaken prior to project commencement to determine the baseline:

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## (7.8)

Where: *total* = *Bld,Bla* or *Blp*

*ci* = The calculated confidence interval at 90% confidence

2. Where sampling is undertaken after project commencement to determine carbon under the project scenario:

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## (7.9)

Where

*total* = *Bld, Bla* or *Blp*

*ci* = The calculated confidence interval at 90% confidence

# 6 PARAMETERS

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Bls* |
| Data unit: | t |
| Description: | Litter biomass per stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Litter biomass per stratum |
| Any comment: |  |
| Data Unit / Parameter: | Bld |
| Data unit: | t |
| Description: | Dispersed litter biomass per stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Dispersed litter biomass per stratum |
| Any comment: |  |
| Data Unit / Parameter: | Bla |
| Data unit: | t |
| Description: | Accumulated litter biomass per stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Accumulated litter biomass per stratum |
| Any comment: |  |
| Data Unit / Parameter: | Blp |
| Data unit: | t |
| Description: | Point source litter biomass per stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | point source litter biomass per stratum |
| Any comment: |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Data Unit / Parameter: | | Blpy | |
| Data unit: | | t | |
| Description: | | Point source litter biomass per sampled point source | |
| Source of data: | | Calculated | |
| Justification of choice of data or description of measurement methods and procedures applied: | | point source litter biomass per stratum | |
| Any comment: | |  | |
| Data Unit / Parameter: | | A | |
| Data unit: | | Hectares | |
| Description: | | Stratum area | |
| Source of data: | | From field surveys or remote sensing | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Stratum area | |
| Any comment: | |  | |
| Data Unit / Parameter: | | Lw | |
| Data unit: | | Kg | |
| Description: | | Total dry weight of the collected litter | |
| Source of data: | | Field survey | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Total dry weight of the collected litter | |
| Any comment: | |  | |
| Data Unit / Parameter: | | n | |
| Data unit: | | # | |
| Description: | | Number of litter plots | |
| Source of data: | | Field survey | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Number of litter plots | |
| Any comment: | |  | |
| Data Unit / Parameter: | | PSl | |
| Data unit: | | m2 | |
| Description: | | Plot size of the litter plot | |
| Source of data: | | Field survey | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Plot size of the litter plot | |
| Any comment: | |  | |
| Data Unit / Parameter: | | Aal | |
| Data unit: | | Hectares | |
| Description: | | Area within the stratum covered with accumulated litter | |
| Source of data: | | Field Survey or remote sensing | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Area within the stratum covered with accumulated litter | |
| Any comment: | |  | |
| Data Unit / Parameter: | | z | |
| Data unit: | | # | |
| Description: | | number of sample points for point source litter sampling | |
| Source of data: | | Field survey | |
| Justification of choice of data or description of measurement methods and procedures applied: | | The number of sample points for point source litter sampling at a given source | |
| Any comment: | |  | |
| Data Unit / Parameter: | | Dl | |
| Data unit: | | g/cm3 | |
| Description: | | Density of the litter | |
| Source of data: | | Laboratory measurement of field samples | |
| Justification of choice of data or description of measurement methods and procedures applied: | | Density of the litter collected at the point source sampling points | |
| Any comment: | |  | |

|  |  |
| --- | --- |
| Data Unit / Parameter: | PS# |
| Data unit: | # |
| Description: | Number of accounted point sources per hectare |
| Source of data: | Field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of accounted point sources per hectare |
| Any comment: |  |
| Data Unit / Parameter: | Dpx |
| Data unit: | cm |
| Description: | Depth of the litter layer at measurement point x |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The depth of the litter layer at measurement point x (point 1 being closest to the center of the source), averaged across all of the samples, |
| Any comment: |  |
| Data Unit / Parameter: | rx |
| Data unit: | cm |
| Description: | Distance from the center to measurement point x |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The distance from the center to measurement point x for each point source sampling point |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

None

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-6

ESTIMATION OF CARBON STOCKS IN THE DEAD WOOD POOL

Version 1.0

16 November 2012

Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**TABLE OF CONTENTS**

[1 SOURCES 2](#_Toc44315)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc44316)

[3 DEFINITIONS 2](#_Toc44317)

[4 APPLICABILITY CONDITIONS 2](#_Toc44318)

[5 PROCEDURES 2](#_Toc44319)

[6 PARAMETERS 7](#_Toc44320)

[7 REFERENCES AND OTHER INFORMATION 15](#_Toc44321)

# 1 SOURCES

None

# 2 SUMMARY DESCRIPTION OF THE MODULE

The module consists of methods for sampling and calculating dead wood biomass where dead wood is distributed across the stratum, as well as where it is concentrated in piles or windrows.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Dead Wood:** | See *VCS Program Definitions.* |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Stratification:** | The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

### Introduction

Dead wood will be found in one of two conditions:

* Standing
* Lying

Standing dead wood must be inventoried using the same plot methods as those laid out in the module *TRS-4 Estimation of Carbon in Living Plant Biomass*, Step 2(C) for measurement of living trees using plots. This work should be undertaken at the same time as the inventory of living trees.

Lying dead wood includes all lying organic matter greater than 10 cm in diameter, and may be found in two distributions:

* Distributed – the dead wood is scattered across the ground where it fell
* Concentrated – the dead wood has been concentrated into piles, windrows, etc, usually by human action, but also possibly by the action of water or other natural agents

Therefore total dead wood in the stratum must be quantified as:

** (8.1)

Where:

*Bdws*  = Total dead wood biomass in the stratum, tonnes

*Bdwt =* Standing dead wood biomass in the stratum, tonnes

*Bdwd* = Distributed dead wood biomass in the stratum, tonnes

*Bdwc* = Concentrated dead wood biomass, tonnes

Separate methods will be used to inventory distributed and concentrated dead wood.

**Method A: Inventorying distributed dead wood**

Distributed dead wood must be inventoried using a line intersect method, using the following steps:

### Step 1: Establishment of lines

Dead wood is measured along lines laid out throughout the stratum. Lines must be laid out systematically, cover the entire area, and run through all variations in ecosystem make-up, process, or conditions which are found within the stratum, in an unbiased manner. For instance, a typical approach might be to lay out lines beginning from a randomly located starting point, running in a randomly selected direction, evenly spaced across the block. Note, however, that even with a random starting point and direction, the project proponent must ensure that sampling is not biased, as could occur if the random direction and spacing happened to coincide with repetitions of natural or manmade features such as roads or stream channels. Lines are divided into 100m segments.

### Step 2: Measurement of dead wood

For each piece of dead wood greater than 10 cm in diameter that crosses the line. measure the average diameter perpendicular to the grain of the piece at that point. Where a piece of dead wood is not round, this may require several measurements. Optionally the average can be calculated as the maximum diameter measured plus the minimum diameter measured, divided by two. Each measured piece is also identified as by species and soundness. Soundness should be classified as sound, intermediate or rotten. Defining these classes will be at the discretion of the field team, but the classes must be discrete, cover the full range of dead wood found, and be clearly identifiable based on the use of consistent field techniques. Typical field techniques may include assessment of the degree of penetration with a knife or other instrument. A clear dividing line must also be defined between dead wood and material sufficiently rotted that it will be quantified as litter or humus, to avoid double counting. Typically any material which substantially retains the shape of the original wood is considered dead wood, while material which has disintegrated is defined as litter or humus, depending on the degree of disintegration. Samples of each species and soundness class found must be taken and the dry mass of the material (g/cm3) determined.

### Step 3: Calculation of dead wood cross section per 100 m interval

For each 100m section of the line, the following equation must be used to calculate the mass per centimeter of length for each piece of wood detected along the line section.

*A number with a number on it

AI-generated content may be incorrect.* (8.2)

Where:

*DWl* = The mass of the wood per unit of length, g/cm

*dwd* = The average diameter of the piece of dead wood at the line, cm *WMs* = Density of the wood of the species and soundness class, g/cm3

The factor DW l must then be summed for all pieces of wood in each 100m line segment:

*A mathematical equation with letters and numbers

AI-generated content may be incorrect.*

(8.3)

Where:

*DWs* = The total mass of the wood for an area of 1 cm wide by 100m long, g/10,000cm2

*DWl* = The mass of the wood per unit of length, g/cm2

*w*  = The pieces of wood found in the line segment

*x* = The total number of pieces of wood found in the line segment

## Step 4: Statistical analysis

Determine the confidence interval of the factor DWs for the lines segments found in the stratum. The standard error of the mean should be less than ± 10% with 90% confidence interval, subject to the guidance given in the section on statistics below.

If post-stratification is undertaken, confidence intervals must be recalculated.

## Step 5: Calculation of dead wood biomass per stratum

Dead wood biomass within the stratum must be calculated using the following equation:

*A black text with a black dot

AI-generated content may be incorrect.* (8.4)

|  |  |  |
| --- | --- | --- |
| Where: |  | |
| *Bdwd* | = | Distributed dead wood biomass in the stratum, tonnes |
| *A* | = | The area of the stratum, hectares |
| *ls#* | = | The number of 100m line segments sampled in the stratum, number |
| *DWs* | = | The total mass of the wood for an area of 1 cm wide by 100m long, g/10,000cm2 |
| *y* | = | The number of line segments sampled |

**Method B: Inventorying concentrated dead wood**

Where dead wood has been concentrated into windrows or piles, the following steps must be undertaken:

## Step 1: Estimate the amount of dead wood piles or windrow

Estimate the number of dead wood piles, or the length (meters) of windrows in the stratum. This can often be efficiently accomplished using remote sensing, since piles or windrows are often big enough to show up at higher resolutions. Where distinct size classes of piles or windrows exist, these must be accounted separately. Where remote sensing cannot be used, the following estimation techniques must be used:

* Windrows: lay out a line or lines perpendicular to the direction of the windrows, and reasonably covering the area, similar to the line intersect methods used for the distributed dead wood above, and count the number of windrows crossed. The total length of windrow must be calculated using the following equation:

*A close up of a number

AI-generated content may be incorrect.*

(8.5)

|  |  |
| --- | --- |
| Where: |  |
| *WL*  = | The total length of windrows in the stratum, meters |
| *w#* = | The number of windrows counted during the survey, number |
| *ls#* = | The total number of 100m line segments surveyed along the lines, number |
| *A* = | The areas of the stratum, hectares |

* Piles: lay out 1 hectare plots by locating the corners of a 100m by 100 m area, and count the number of piles within the plot. Plots must be laid out systematically, and must be located throughout the stratum. The total number of piles will be:

*A black text on a white background

AI-generated content may be incorrect.*

(8.6)

|  |  |
| --- | --- |
| Where: |  |
| *P#* = | The number of piles in the stratum, number |
| *Totp* = | The total number of piles counted in all of the plots, number |
| *plt#* = | The total area plotted, hectares, (= the number of plots) |
| *A*  = | The area of the stratum, hectares |

## Step 2: Estimate the volume per pile or meter of row

Using measurements and standard geometric formulae, measure a number of windrows or piles, and estimate the gross volume per pile, or per meter of windrow. Sufficient measurements should be taken to achieve a standard error of the mean of less than 10% with 90% confidence, subject to the guidance given in the section on statistics below. As noted above, where distinct size classes of piles or windrows exist, and where those size classes have been counted or measured for length separately, the volumes for each size class must be summarized separately.

## Step 3: Estimate the concentration of dead wood

Estimate the percentage of the volume of the pile or windrow that is made up of wood. This can be done by cutting apart a measured portion of a pile or row, and measuring and calculating the volume of each piece of wood in it. During this process wood must be assessed for soundness, as discussed for dispersed dead wood above, and species, where species can be identified.

## Step 4: Estimate the average dead wood dry specific gravity

Samples of each combination of species and soundness class found must be taken and the mass of the material (g/cm3) determined. Based on the percentage of each species and soundness class identified, calculate the average dead wood dry specific gravity.

## Step 5: Calculate the total dead wood biomass in piles and windrows

Total dead wood biomass in piles and windrows per stratum must be calculated using the following formula:

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | (8.7) |
| Where: |  |  |
| *Bdwc* | = | Biomass of dead wood in piles and windrows, t |  |
| *s* | = | Number of different windrow sizes # |  |
| *wls* | = | The length of windrow in size class w in the stratum, m |  |
| *wvs* | = | The volume of the windrow in size class s per meter of length, m3/m |  |
| *%wws* | = | The percentage of wood by volume in windrow size class s, m3/m3 |  |
| *WMaw* | = | The average specific gravity of the dry wood in the windrows, t/m3 |  |
| *p* | = | Pile sizes |  |
| *r* | = | The number of different pile size classes |  |
| *#pr* | = | The number of piles in size class r in the stratum |  |
| *pvr* | = | The average pile volume in size class r, m3 |  |
| *%pwr* | = | The percentage of wood by volume in size class r. m3/m3 |  |
| *WMap* | = | The average density of the dry wood in piles, t/m3 |  |

## Statistical Calculations

Calculate the standard deviation and the confidence interval for total carbon for each type of dead wood independently. Where the confidence interval exceeds +/- 10% with 90% confidence for any of the dead wood types within the stratum, the project proponent must undertake one or more of three actions:

1. Re-stratify: Where the variance in the samples appears to be correlated to geographic or other factors, re-stratification should be considered, as discussed in the module *TRS-1 Methods to Determine Stratification*. If re-stratification is undertaken, confidence intervals should be recalculated for the new strata. Re-stratification requires the installation of further randomly or systematically located plots if the confidence interval in one of the new strata fails to meet the required confidence standards, unless the project proponent chooses to utilize option c, below, for that stratum.
2. *A black text with a white background

   AI-generated content may be incorrect.*Increase the number of line segments or samples: Where the variance appears to be inherent to and distributed across the stratum, the project proponent may choose to install further line segments or samples. An estimate of the required number of further line segments or samples can be calculated, using the equation 8.8, and further line segments or samples installed, located systematically or randomly.

(8.8)

Where

N = Total number of plots expected to be required

T = Student t-test 0.90 value for n-1, n being the number of plots already established

s = Standard deviation for the existing plot values

m = Mean value of the variable from the existing plots

Recalculate the value of *wvs*, pvr or DWs

1. In some cases, due to project size or other factors, installing enough lines or samples to meet the required confidence interval for a given dead wood type may not be economically viable. In these cases, the project proponent may proceed with data gathered to a lower confidence interval. However, the project proponent must recalculate the total estimated biomass for the relevant dead wood type (*wvs*, pvr or DWs) as follows:

* 1. Where sampling is undertaken prior to the project start date to determine the baseline:

A black and white text

AI-generated content may be incorrect. (8.9)

Where:

*total* = *wvs*, pvr or DWs

*ci* = The calculated confidence interval at 90% confidence

* 1. *A black and white text

     AI-generated content may be incorrect.*Where sampling is undertaken after the project start date to determine carbon under the project scenario:

(8.10)

Where

*total* = *wvs*, pvr or DWs

*ci* = The calculated confidence interval at 90% confidence.

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | Bdws |
| Data unit: | tonnes |
| Description: | Total dead wood biomass in the stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The mass of the wood per unit of length on the line intersect |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | DWl |
| Data unit: | g/cm |
| Description: | Mass of the wood per unit of length |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The mass of the wood per unit of length on the line intersect |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | dwd |
| Data unit: | cm |
| Description: | Average diameter of the piece of dead wood at the line |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average diameter of the piece of dead wood at the line |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | WMs |
| Data unit: | g/cm3 |
| Description: | Density of the wood of a species |
| Source of data: | Measured from samples |
| Justification of choice of data or description of measurement methods and procedures applied: | The dry mass of the wood of a species |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | DWs |
| Data unit: | g/cm |
| Description: | Mass of the wood per unit of length, |
| Source of data: | Field Survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The total mass of the wood per unit of length for the 100m line segment, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | W |
| Data unit: | # |
| Description: | Pieces of wood found in the line segment |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The pieces of wood found in the line segment |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | x |
| Data unit: | # |
| Description: | Total number of pieces of wood |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The total number of pieces of wood found on the line segment. |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | Bdwd |
| Data unit: | tonnes |
| Description: | Distributed dead wood biomass in the stratum |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Distributed dead wood biomass in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | A |
| Data unit: | hectares |
| Description: | Area of the stratum |
| Source of data: | Field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The area of the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | ls# |
| Data unit: | # |
| Description: | Number of 100m line segments |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of 100m line segments sampled in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | ls |
| Data unit: | # |
| Description: | Line segments sampled |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The line segments sampled |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | y |
| Data unit: | # |
| Description: | Number of line segments sampled |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of line segments sampled |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | WL |
| Data unit: | M |
| Description: | Total length of windrows |
| Source of data: | Field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The total length of windrows in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | w# |
| Data unit: | # |
| Description: | Number of windrows counted |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of windrows counted during the survey |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | P# |
| Data unit: | # |
| Description: | Number of piles |
| Source of data: | Field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of piles in the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | Totp |
| Data unit: | # |
| Description: | Total number of piles counted |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The total number of piles counted in all of the plots |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | plt# |
| Data unit: | Hectares |
| Description: | Total area plotted |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The total area plotted, hectares, (= the number of plots) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | z |
| Data unit: | # |
| Description: | Windrow size classes |
| Source of data: | Determined from the field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | number of different windrow sizes |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | Bdwc |
| Data unit: | T |
| Description: | Biomass of dead wood in piles and windrows |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Biomass of dead wood in piles and windrows |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | wls |
| Data unit: | M |
| Description: | The length of windrow in size class w in the stratum, m |
| Source of data: | Field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The length of windrow in size class s, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | wvs |
| Data unit: | m3/m |
| Description: | Volume of the windrow in size class z |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The volume of the windrow in size class s per meter of length |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | %wws |
| Data unit: | % |
| Description: | Percentage of wood by volume in windrow size class s |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The percentage of wood by volume in windrow size class s |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | WMaw |
| Data unit: | t.m-3 |
| Description: | Average specific gravity of the dry wood in the windrows |
| Source of data: | Measurement of samples taken in the field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average specific gravity of the dry wood in the windrows |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | p |
| Data unit: | # |
| Description: | Pile sizes |
| Source of data: | Classified from field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | Pile sizes |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | r |
| Data unit: | # |
| Description: | Pile size classes |
| Source of data: | Classified from field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The pile size classes |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | #pr |
| Data unit: | # |
| Description: | Number of different pile size classes |
| Source of data: | Classified from field survey or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | the number of different pile size classes |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | pvr |
| Data unit: | m3 |
| Description: | Average pile volume in size class r, |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average pile volume in size class r, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | %pwr |
| Data unit: | m3/m3 |
| Description: | Percentage of wood by volume in size class r. |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The percentage of wood by volume in size class r. |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | WMap |
| Data unit: | t/m3 |
| Description: | Average specific gravity of the dry wood in piles |
| Source of data: | Measurement of samples taken in the field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average specific gravity of the dry wood in piles |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | Bdwt |
| Data unit: | Tonnes |
| Description: | Standing dead wood |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Standing dead wood biomass in the stratum |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

None

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-7

ESTIMATION OF WOODY BIOMASS HARVESTING AND UNTILIZATION

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**TABLE OF CONTENTS**

[1 SOURCES 2](#_Toc7680)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc7681)

[3 DEFINITIONS 2](#_Toc7682)

[4 APPLICABILITY CONDITIONS 2](#_Toc7683)

[5 PROCEDURES 2](#_Toc7684)

[6 PARAMETERS 5](#_Toc7685)

[7 REFERENCES AND OTHER INFORMATION 5](#_Toc7686)

# SOURCES

None

# SUMMARY DESCRIPTION OF THE MODULE

This module provides options for quantifying the amount of annual wood harvest occurring within the project area on an annual basis.

# DEFINITIONS

|  |  |
| --- | --- |
| **Agent:** | A person or organization undertaking actions which impact the management of carbon pools and emissions. |
| **Complete Harvest Inventory:** | Inventory of wood products based on the knowledge of total harvest. |
| **Partial Harvest Inventory:** | Inventory of wood products based on known fraction of total harvest. Known fraction can be used to extrapolate to total harvest. |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities |
| **Remote Sensing and Forest Inventory:** | Inventory of wood biomass harvested using remote sensing and forest inventory data. |

# APPLICABILITY CONDITIONS

None

# PROCEDURES

**Introduction:**

Wood harvest from an area can be quantified in a number of ways. The following steps are hierarchical, with the most preferred (most accurate) method being given first, and a series of less preferred options being given as subsequent methods.

Option 1 must be used if complete records are available. If incomplete records are available, use Option 2. If no records are available, use Option 3.

The output of this module is a table for each of the years for which data is gathered, showing the volume of timber extracted from within the project area by species and grade (Vex,ty,j,t). In some cases, where measurement systems include adjustment factors for defects such as mill losses (eg, the hoppus system, which estimates log volumes in terms of net milled timber volumes rather than total volume), data from these measurement systems must be adjusted using an appropriate factor, to generate data on the total volume extracted.

### Option 1 – Complete harvest inventory

This option must be used if complete records showing the location(s) of harvesting, the amount and grade of each species harvested from each location are available. These records may be available:

* From the agent(s) undertaking the harvesting;
* From the wood buyers, mills, or other users;
* From government records for taxation or other purposes;
* From certifying bodies or other third parties; or,  From a combination of these sources.

If these records are available, they must be checked against remote sensing images, field surveys, or available forest inventories to ensure that the data reported correlates with what is found in the field. If discrepancies are found, the reason for these discrepancies should be discussed with the parties providing the information, to determine if a reason exists for the discrepancy.

Where a discrepancy exists which is not explicable by the parties providing the inventories, the project proponent must choose the most conservative of values, and document the nature of the discrepancy.

### Option 2 – Partial harvest inventory

This option must be used where some inventory of actual harvest is available, but where complete records are not available (eg. species and grade breakdowns). This will typically occur where:

* Records of the volumes harvested are available, but species and grade breakdowns are partially or wholly missing.
* Records of harvest are only available for some of the areas harvested.
* Records of harvest are available for some agents, but not others.

Where data is available from harvest records, the available data must be used, subject to the checking described in Option 1. Missing data must be filled in as set out below.

Where data for species and grade breakdowns are missing, species and grade breakdowns can be filled in from:

* Forest inventory data for the areas harvested gathered prior to harvest.
* Typical species and grade breakdowns from the area, based on mill records, records from regulatory bodies, breakdowns from forest inventories for other areas, or existing research.
* Regional estimates.

Where data for volumes from some areas are missing, data can be filled in from:

* Forest inventory data for the areas harvested gathered prior to harvest.
* Volume data for other, parallel areas.
* Forest inventory data from other, parallel areas.
* Regional estimates.

Where data on the forest harvest by some agents are missing, data can be filled in from:

* Maps, remote sensing or ground surveys to delineate the areas harvested and to estimate the intensity of harvest.
* Volume, species and grade data from other agents working in the area, or from forest inventories, adjusted for observed differences in forest type or logging intensity.
* Regional estimates of per hectare volume, species and grade breakdowns.

Where-ever possible more than one source should be used to check data, and conservative estimates should be used.

### Option 3 – Remote sensing and forest inventory

Where no inventory of harvested wood is available, project proponents must estimate values for the missing data based on estimation as set out below.

Where no data on areas harvested and timing of harvest are available, estimate values of missing data from:

* Maps, remote sensing or ground surveys.

Where no data on intensity of harvest are available, estimate values of missing data from:

* Remote sensing or ground surveys.

Where no data on wood removed per unit of area, by species, are available, estimate values of missing data from:

* Forest inventories from the areas logged or similar areas within the project area.
* Existing harvest data from other harvest operations working in the vicinity of the project area, in similar ecotypes and stands.
* Existing forest inventories from areas in the vicinity of the project area, in similar ecotypes and stands.
* Regional estimates of per hectare volume extracted from forests of these types.

Where no data on grade breakdowns are available, estimate values of missing data from:

* Forest inventories from the areas logged or similar areas within the project area.
* Existing grade breakdowns from other harvest operations working in the vicinity of the project area, in similar ecotypes and stands, or from mills or buyers of wood from these operations
* Existing forest inventories from areas in the vicinity of the project area, in similar ecotypes and stands.
* Regional estimates of grade breakdowns from forests of these types.

# PARAMETERS

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Vex,ty,j,t* |
| Data unit: | m3 |
| Description: | Volume of timber extracted from within the project area (does not include slash left onsite) by species *j* and wood product class *ty* at time *t* |
| Source of data: | Described in this module |
| Justification of choice of data or description of measurement methods and procedures applied: | Described in this module |
| Any comment: |  |

# REFERENCES AND OTHER INFORMATION

None

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-9

ESTIMATION OF DOMESTICATED ANIMAL POPULATIONS

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## TABLE OF CONTENTS

[1 SOURCES 2](#_Toc6378)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc6379)

[3 DEFINITIONS 2](#_Toc6380)

[4 APPLICABILITY CONDITIONS 2](#_Toc6381)

[5 PROCEDURES 2](#_Toc6382)

[6 PARAMETERS 4](#_Toc6383)

[7 REFERENCES AND OTHER INFORMATION 4](#_Toc6384)

# SOURCES

Safley LM, P. Jun, M. Gibbs, CH4 and N20 emissions from livestock manure, IPCC background paper

# SUMMARY DESCRIPTION OF THE MODULE

The module provides methods for estimating domesticated animal populations on an average annual basis, broken down by type of animal, as well as the manure management systems associated with each population.

# DEFINITIONS

**Livestock:** Domesticated animals including dairy cattle, non-dairy cattle, buffalo, sheep, goats, camels, horses, mules, asses, swine, poultry, alpacas and llamas

# APPLICABILITY CONDITIONS

None

# PROCEDURES

Project proponents must gather data on two basic variables: livestock populations by type, and manure management system.

**Livestock Populations**

Data must be collected on the average annual population of livestock for each of the species listed below. Note that the population may vary depending on the time at which the census is taken. For example, a census taken before calves are born yields a lower number of animals than a census taken after calves are born. Therefore, the average annual population must represent estimate of the average livestock population over an entire year. Livestock types which must be included in a census are:

* Dairy cattle
* Non-dairy cattle
* Buffalo
* Sheep
* Goats
* Camels
* Horses
* Mules and asses
* Swine
* Poultry
* Lamas
* Alpacas

Dairy cattle populations must be recorded separately from other cattle populations. Dairy cattle are defined as mature cows producing milk in commercial quantities for human consumption, and are managed differently from non-dairy cattle. This generally results in differences in composition and methane production potential between dairy and non-dairy cattle manure. Additionally, dairy cattle manure is often managed differently from non-dairy cattle manure.

In some countries, there are two types of dairy cows: high-producing, “improved” breeds in commercial operations and low-producing breeds managed with traditional methods. If there are two types of dairy cows within the project area, dairy cow populations must be separated into these two groups. The dairy cow group does not include cows used mainly for producing calves or for draft power (for example, plowing), as those cows are accounted for in non-dairy cattle group.

In addition, livestock populations must be described in terms of warm or cool temperature climates for purposes of estimating livestock manure emissions. Data on the annual average temperature of the regions where livestock are managed must be categorized as follows:

* Areas with annual average temperatures less than 15°C are defined as cool;
* Areas with annual average temperatures from 15°C to 25°C inclusive are defined as temperate, and
* Areas with annual average temperatures greater than 25°C are defined as warm.

The fraction of each livestock population falling into each climate area must be estimated, if the area contains more than one climate. This data can be developed from local climate maps and other sources.

**Manure Management**

In addition to the livestock population data described above, data must also be collected on the percentage of manure from each livestock type managed with each management system. The types of manure management systems are:

* Pasture/Range/Paddock - The manure from pasture and range grazing animals is allowed to lie as is, and is not managed.
* Daily Spread - Manure is collected in solid form by some means such as scraping. The collected manure is applied to fields regularly (usually daily).
* Solid Storage - Manure is collected as in the daily spread system, but is stored in bulk for a long period of time (months) before any disposal.
* Dry Lot - In dry climates animals may be kept on unpaved feedlots where the manure is allowed to dry until it is periodically removed. Upon removal, the manure may be spread on fields.
* Liquid/Slurry - These systems are characterized by large concrete-lined tanks built into the ground. Manure is stored in the tank for six or more months until it can be applied to fields. To facilitate handling as a liquid, water may be added to the manure.
* Anaerobic Lagoon - Anaerobic lagoon systems are characterized by flush systems that use water to transport manure to lagoons. The manure resides in the lagoon for periods from 30 days to over 200 days. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
* Pit Storage - Liquid swine manure may be stored in a pit while awaiting disposal – the length of storage must be documented
* Anaerobic Digester - The manure, in liquid or slurry form, is anaerobically digested to produce methane gas for energy.
* Burned for fuel: manure is collected and dried in cakes and burned for heating or cooking.

If local, regional or country-specific data on manure management practices exists it must be used. If it is not available, default IPCC manure management practice data for major regions based on Safley, et al. (1992) must be used. If the available data predates current manure management practices within the project area; it must be updated to reflect such current practices.

The project proponent should document the data sources and timing of data collection for all data on livestock populations and manure management systems.

# PARAMETERS

None

# REFERENCES AND OTHER INFORMATION

Safley LM, P. Jun, M. Gibbs, CH4 and N20 emissions from livestock manure, IPCC background paper: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4\_2\_CH4\_and\_N2O\_Livestock\_Manure.pdf (Last visited 16-09-2011)

UNFCCC CDM, *Tool for testing significance of GHG emissions in A/R CDM project activities*, (Last visited

16-09-2011, http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf)

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-8

ESTIMATION OF CARBON STOCKS IN THE LONG LIVED WOOD PRODUCTS POOL

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1. SOURCES 2](#_Toc28302)

[2. SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc28303)

[3. DEFINITIONS 2](#_Toc28304)

[4. APPLICABILITY CONDITIONS 2](#_Toc28305)

[5. PROCEDURES 2](#_Toc28306)

[6. PARAMETERS 6](#_Toc28307)

[7. REFERENCES AND OTHER INFORMATION 9](#_Toc28308)

# SOURCES

VCS module *VMD0005 [Estimation of carbon stocks in the long-term wood products pool (CP-W), v1.0](http://www.v-c-s.org/methodologies/VMD0005)*

# SUMMARY DESCRIPTION OF THE MODULE

This module provides a method for estimating carbon stocks and changes in carbon stocks in the harvested wood products pool, based on the end use of the wood removed or projected to be removed from the project area. Estimates of harvest volumes are determined using the module *TRS-7 Estimation of Woody Biomass Harvesting and Utilization*.

# DEFINITIONS

**Project Area:** The area or areas of land on which the project proponent will undertake the project activities.

**Wood Density:** The mass per unit volume of the dry wood of a given species.

# APPLICABILITY CONDITIONS

None

# PROCEDURES

This module estimates annual sequestration of carbon stock in wood products (*CG\_WPt*) following the conceptual framework detailed in Winjum et al 1998. Where the estimates of harvested wood volumes are determined for the project area as a whole, the calculation of carbon sequestration in wood products will also be undertaken for the project area as a whole and no stratification is used. However, if estimates of harvested wood volumes are undertaken separately for strata within the project area and wood from each stratum produces a different mix of wood products, the equations given below must be used separately for each stratum, and the results summed to provide the amount sequestered for the area as a whole.

Note that the oxidization factors are subject to ongoing updating as further research is undertaken, and the most recent factors applicable to the types of wood and products produced must be used.

**Step 1:** Calculate the biomass carbon of the volume extracted by wood product type *ty* over a given period *p* from within the project area:

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AI-generated content may be incorrect.*

(10.1)

|  |  |  |
| --- | --- | --- |
| Where: |  |  |
| *CXB,ty,p* | = | Total carbon stock of extracted biomass from within the project areaby class of wood product *ty* over a given time period *p*; t C |
| *Vex,ty,j,p* | *=* | Volume of timber extracted from within the project area(does not include slash left onsite) by species *j* and wood product class *ty* over a given time period *p*; m3 |
| *Dj* *CFj* | =  *=* | Wood density (specific gravity) of species *j*; t d.m.m-3  Carbon fraction of biomass for tree species *j*; t C t-1 d.m. |
| *j* | *=* | *1, 2, 3 … S* tree species |

*ty =* Wood product class – defined here as sawnwood, wood-based panels, other industrial round wood, paper and paper board, and other

**Step 2:** Calculate the proportion of biomass carbon extracted during the time period *p* that remains sequestered in long-term wood products after a number of years *y* since the wood products were initially created. All factors are derived from Winjum et al.1998.

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AI-generated content may be incorrect.

(10.2)

Where:

|  |  |
| --- | --- |
| *Cwpy* = | Carbon stock sequestered in wood products created over a given period *p*, that remain sequestered after a number of years *y* since the wood products were created; t C |
| *CXB,ty,p* = | Total carbon stock of extracted biomass from within the project areaby class of wood product *ty* over a given period *p*, t C |
| *WWty(\*) =* | Wood waste fraction of wood products *ty* immediately emitted through mill inefficiency; t C\* |
| *SLFty(\*\*) =* | Short-lived fraction of wood products of type *ty* that will be emitted to the atmosphere within 3 years of timber harvest; t C *\*\** |
| *OFty,y(\*\*\*) =* | Oxidized fraction of wood products of type *ty* whose carbon will be emitted between 3 and 100 years after creation of the harvested wood product, remaining at year *y* after the wood products were created; t C |
| *ty =* | Wood product class (defined here as sawnwood, wood-based panels, other industrial round wood, paper and paper board, and other) |
| *z* = | number of wood products classes *ty* |
| *y =* | 1,2,3… y years elapsed since the wood products were created. |

Values for WW, SLF and OF must be derived based on the following guidance:

Wood waste fraction (WW)\*:

Winjum et al 1998 indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries, 24% for developing countries. *WW* is therefore equal to *CXB,ty,p* multiplied by 0.19 for developed countries and 0.24 for developing countries.

Short-lived fraction (SLF)\*\*:

Fraction of wood products that are oxidized within 3 years after creation, assumed to be 3/5 of the wood products that would have been oxidized within 5 years of creation, as per the estimates of the short lived proportion (slp) given in Winjum et al 1998 (applicable internationally):

Estimate the short-lived fraction using the following short lived proportion (slp) factors by wood product class:

Sawnwood = 0.12

Woodbase panels = 0.06

Other industrial round wood = 0.18

Paper and Paperboard = 0.24

Note that these factors for short-lived wood products are subject to ongoing updating as further research is undertaken, and the most recent factors applicable to the types of wood and products produced must be used, considering that only wood products that decay within 3 years may be considered in the short-lived fraction.

Therefore SLF will be equal to:

(10.3)

Where:

|  |  |
| --- | --- |
| *SLFty =* | Short-lived fraction of wood products that will be emitted to the atmosphere within 3 years of timber harvest from wood product *ty*; t C |
| *CXB,ty,p* = | Total carbon stock of extracted biomass from within the project areaby class of wood product *ty* over a given period p; t C |
| *WWty =* | Wood waste - fraction of extracted biomass carbon immediately emitted through mill inefficiency from wood product *ty*; t C |
| *slp =* | Short-lived proportion: Using the factors for the product classes given above. |
| *ty =* | Wood product class (defined here as sawnwood, wood-based panels, other industrial round wood and paper and paperboard) |

Additional oxidized fraction (OF)\*\*\*:

Winjum et al 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 97 years to give the additional proportion that is oxidized between 3 and 100 years after initial harvest (Table 1):

Table 1: The fraction oxidized (fo) factors for wood products oxidized between 3 and 100 years after initial harvest by wood product class and forest region

|  |  |  |  |
| --- | --- | --- | --- |
| **Wood Product Class** | **Boreal** | **Temperate** | **Tropical** |
| Sawnwood | 0.39 | 0.62 | 0.86 |
| Woodbase panels | 0.62 | 0.86 | 0.98 |
| Other industrial round wood | 0.86 | 0.98 | 0.99 |
| Paper and paperboard | 0.39 | 0.62 | 0.99 |

Note that these oxidization factors are subject to ongoing updating as further research is undertaken, and the most recent factors applicable to the types of wood and products produced must be used, considering that the oxidized fraction of wood products must include those which oxidize between 3 and 100 years.

As per VCS guidance this oxidization is presumed to occur following a linear decay function over a 20 year period.

*OF* is therefore equal to:

** (10.4)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Where | |  |  | | |
| *OFty,y* | | *=* | Oxidized fraction of wood products of type *ty* created during period *p* whose carbon will be emitted between 3 and 100 years after creation of the harvested wood product, remaining at year *y* after the wood products were created; t C | | |
| *CXB,ty.p* | | = | Total carbon stock of extracted biomass from within the project area by class of wood product *ty* over a given period p; t C | | |
| *WWty* | *=* | | Wood waste fraction of wood products *ty* immediately emitted through mill inefficiency; t C |
| *SLFty* | *=* | | Fraction of wood products of type *ty* that will be emitted to the atmosphere within 3 years of timber harvest; t C |
| *fo* | *=* | | Fraction oxidized – see Table 1 for defaults; t C t C-1 |
| *ty* | *=* | | Wood product class (defined here as sawnwood, wood-based panels, other industrial round wood, paper and paper board, and other) |
| *y* | = | | the number of years since the wood products were created. |
| *m* | = | | the number of years since the wood products were created, *y*, where for all *y* >20, *m*=20 |

**Step 3**: Calculate the total HWP remaining *t* years after the project start date, consisting of the HWP remaining out of the products created during each period *p* since project commencement (*t*=0), using the following equation.

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AI-generated content may be incorrect.*

(10.5)

Where

*Cwpt* = The total carbon contained in harvested wood products at time *t*, tC

*Cwpy* = Carbon stock sequestered in wood products created over a given period *p*, that remain sequestered after a number of years *y* ; t C

*y* = The number of years since the wood products in the given period *p* were created

# PARAMETERS

|  |  |
| --- | --- |
| Data Unit / Parameter: | C*XB,ty,p* |
| Data unit: | tonnes C |
| Description: | Extracted biomass carbon during period p |
| Source of data: | Estimated from census |
| Justification of choice of data or description of measurement methods and procedures applied: | Total carbon stock of extracted biomass from within the project area by class of wood product ty over a given time period p |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Vex,ty,j,p* |
| Data unit: | m3 |
| Description: | Volume |
| Source of data: | Estimated from census |
| Justification of choice of data or description of measurement methods and procedures applied: | Volume of timber extracted from within the project area (does not include slash left onsite) by species j and wood product class ty over a given time period p |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Dj* |
| Data unit: | t d.m.m-3 |
| Description: | Basic wood density |
| Source of data: | Known or measured |
| Justification of choice of data or description of measurement methods and procedures applied: | Basic wood density of species j |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *CFj* |
| Data unit: | t C t-1 d.m |
| Description: | Carbon fraction of biomass |
| Source of data: | Known |
| Justification of choice of data or description of measurement methods and procedures applied: | Carbon fraction of biomass for tree species j |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *p* |
| Data unit: | none |
| Description: | a period over which biomass was extracted |
| Source of data: | Known |
| Justification of choice of data or description of measurement methods and procedures applied: | A period over which biomass was extracted, not exceeding one year in duration. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *t* |
| Data unit: | Years |
| Description: | 1,2,3… t years elapsed since the start of the project activity. |
| Source of data: | Project records |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *j* |
| Data unit: | Species |
| Description: | Tree Species |
| Source of data: | Census |
| Justification of choice of data or description of measurement methods and procedures applied: | 1, 2, 3 … S tree species |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *ty* |
| Data unit: |  |
| Description: | Wood product class |
| Source of data: | Known |
| Justification of choice of data or description of measurement methods and procedures applied: | Wood product class – defined here as z = 5 categories: sawnwood, wood-based panels, other industrial round wood, paper and paper board, and other |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Cwpy* |
| Data unit: | tC |
| Description: | Total carbon stock in wood products pool from period p |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total carbon stock in wood products pool created during a given period p, that remain sequestered after a number of years y since the wood products were created. |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *WWty* |
| Data unit: | tC |
| Description: | Wood waste |
| Source of data: | Winjum et. al., or superseding research |
| Justification of choice of data or description of measurement methods and procedures applied: | The wood waste fraction immediately emitted through mill inefficiency |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *SLFty* |
| Data unit: | tC |
| Description: | Fraction of wood products that will be emitted to the atmosphere within 3 years of timber harvest |
| Source of data: | Winjum et. al., or superseding research |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction of wood products that will be emitted to the atmosphere within 3 years of timber harvest |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *OFty,y* |
| Data unit: | tC |
| Description: | Fraction of wood products that will be emitted to the atmosphere between 3 and 50 years of timber harvest |
| Source of data: | Winjum et. al., or superseding research |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction of wood products of type ty whose carbon will be emitted between 3 and 100 years after creation of the harvested wood product, remaining at year y after the wood products were created; t C |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *slp* |
| Data unit: | dimensionless |
| Description: | Short-lived proportion factor |
| Source of data: | Winjum et. al., or superseding research |
| Justification of choice of data or description of measurement methods and procedures applied: | Short-lived proportion |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *fo* |
| Data unit: | dimensionless |
| Description: | Fraction oxidized |
| Source of data: | Winjum et. al., or superseding research |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction oxidized |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *m* |
| Data unit: | dimensionless |
| Description: | number of years since HWP were created |
| Source of data: | Known |
| Justification of choice of data or description of measurement methods and procedures applied: | the number of years since the wood products were created, y, where for all y >20, m=20 |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Cwpt* |
| Data unit: | tC |
| Description: | Total HWP carbon |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | the total carbon contained in harvested wood products at time t |
| Any comment: |  |

# REFERENCES AND OTHER INFORMATION

Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-10

ESTIMATION OF EMISSIONS FROM DOMESTICATED ANIMALS

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1. SOURCES 2](#_Toc31019)

[2. SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc31020)

[3. DEFINITIONS 2](#_Toc31021)

[4. APPLICABILITY CONDITIONS 2](#_Toc31022)

[5. PROCEDURES 2](#_Toc31023)

[6. PARAMETERS 6](#_Toc31024)

[7. REFERENCES AND OTHER INFORMATION 10](#_Toc31025)

# SOURCES

CDM methodology *AR-AM 0004 Reforestation or afforestation of land currently under agricultural use*

# SUMMARY DESCRIPTION OF THE MODULE

The module provides methods for estimating the emissions of CH4 and N2O both from domesticated animals directly, and from emissions due to the decomposition of manure. Estimates for domesticated animal populations and associated manure management systems are determined using *TRS-9 Estimation of Domesticated Animal Populations*.

# DEFINITIONS

|  |  |
| --- | --- |
| **Emission Factor:** | The average emission rate of a given pollutant for a given source, relative to the intensity of a specific activity. |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Significant:** | A pool or source is significant if it does not meet the criteria for being deemed de minimis. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. |

# APPLICABILITY CONDITIONS

None

# PROCEDURES

### Introduction

Estimation of emissions of non-CO2 GHGs from domesticated animals must be required where project activities result in one of three conditions:

1. Increases in the total population of a species of domesticated animal, including both animals in the project area, and animals outside the project area as a result of leakage.
2. A change in the feed mix used for the domesticated animals, resulting in increased CH4 or N2O emissions.
3. A change in the manure management systems used for managing manure from domesticated animals, resulting in increased CH4 or N2O emissions.

The methods given below must be undertaken independently for each species or type of domesticated animal (for instance, dairy cattle must be treated separately from other cattle). These estimates must also be undertaken under both the project scenario and the baseline scenario*.*

Emissions from domesticated animals are conservatively excluded when the project activities result in lower emissions from domesticated animals in the project scenario as compared with the baseline scenario. Project scenario emissions must include both emissions from domesticated animals within the project area and any increases in emissions from domesticated animal populations outside of the project area resulting from the project activity. Excluding these emissions from accounting under these conditions is conservative, because it ensures that crediting is not undertaken solely on the basis of estimated reductions in domesticated animal populations.

### Step 1: Estimation of CH4 emissions from enteric fermentation (*El,CH4,ferm*)

*A close up of a word

AI-generated content may be incorrect.*The amount of methane[[11]](#footnote-13) emitted by a population of animals is calculated by multiplying the emission rate per animal by the number of animals. To reflect the variation in emission rates among animal types, the population of animals is divided into subgroups, and an *emission factor* per animal is estimated for each subgroup. As per IPCC GPG 2000 and IPCC 2006 Guidelines for AFOLU, use the following equation[[12]](#footnote-14):

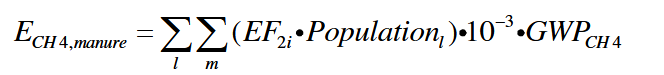
(12.1)

|  |  |
| --- | --- |
| *l*  Where: |  |
| *ECH4,ferm =* | *CH4* emissions from enteric fermentation; tonnes CO2e yr-1 |
| *l =* | Types of livestock |
| *EF1 =* | Enteric CH4 emission factor for the livestock type; kg CH4 head-1 yr-1 |
| *Populationl =* | Number of livestock for the livestock type; heads |
| *GWPCH4 =* | Global warming potential for CH4 (with a value of 21 for the first commitment period); dimensionless |
| *0.001 =* | Conversion factor of kilograms into tonnes; dimensionless |

Country-specific emission factors for enteric CH4 emissions are documented in peer reviewed literature or can be obtained from national GHG inventories. Default values are given in Table 10.10 and 10.11 in the IPCC 2006 Guidelines for AFOLU. Emission factors must be appropriate to the characteristics of the project area. The tables in Annex 10A.1 of the IPCC 2006 Guidelines for AFOLU specify the animal characteristic such as weight, growth rate and milk production used to estimate the emission factors. These tables must be consulted in order to ensure that the local conditions are similar. In particular, data on average milk production by dairy livestock must be analyzed when selecting an emission factor for dairy livestock. To estimate the emission factor, the data in Table 10 A.1 can be interpolated using the data on the local average milk production.

## Step 2: Estimation of CH4 emissions from manure management (*El,CH4,manure*)

The storage and treatment of manure under anaerobic conditions produces CH4. Anaerobic conditions occur most readily when large numbers of animals are managed in a confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms) and where manure is disposed of in liquid based systems. The main factors affecting CH4 emissions are the amount of manure produced and the portion of manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significantquantity of CH4. The temperature and the retention time of storage greatly affect the amount on CH4produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH4 is produced.

**CH4 emissions from manure management for forage-fed livestock can be estimated using IPCC methods[[13]](#footnote-15).

(12.2)

|  |  |  |
| --- | --- | --- |
| Where: |  |  |
| *ECH4,manure* | *=* | CH4 emissions from manure management; tonnes CO2e yr-1 |
| *l* | *=* | Livestock type |
| *m* | = | Manure management system |
| *EF2lm* | *=* | Manure management CH4 emission factor for the livestock type l using the manure management system m; kg CH4 head-1 yr-1 |
| *Populationl* | *=* | Population of livestock type; head |
| *GWPCH4* | *=* | Global warming potential for CH4 (IPCC default value; 21 for the first commitment period); dimensionless |
| *0.001* | *=* | Conversion factor of kilograms into tonnes; dimensionless |

The best estimate of emissions is obtained using country-specific emission factors that have been published in peer-reviewed literature or in the national GHG inventory. Country-specific emission factors must be appropriate to the actual duration of manure storage and the type of manure management system used. If appropriate country-specific emission factors are unavailable, the default emission factorspresented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU may be used. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an appropriate emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project area.

## Step 3: Estimation of N2O emissions from manure management (*El,N2O,manure*) 4

**A black text on a white background

AI-generated content may be incorrect.**Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. The N2O emissions from manure management can be estimated using method provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000[[14]](#footnote-16)

Where:

|  |  |  |
| --- | --- | --- |
| *EN2O,manure* | *=* | N2O emissions from manure management; tonnes CO2e yr-1 |
| *EDirect\_N2O,manure* | *=* | Direct N2O emissions from manure management; tonnes CO2e yr-1 |
| *EIndirect\_N2O,manure* | *=* | Indirect N2O emissions from manure management; tonnes CO2e yr-1 |
| *l* | *=* | livestock type |
| *m* | = | manure management system |
| *Populationl* | *=* | Population of livestock; heads |
| *Nex* | = | Annual average N excretion per livestock head; kg N head-1 yr-1 |
| *EF3* | *=* | Emission factor for N2O emissions from manure management for the livestock group; kg N2O-N (kg N-1) head-1 yr-1 |
| *EF4* | *=* | Emission factor for N2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces; kg N2O-N (kg NH3-  N and NOx-N emitted)-1 head-1 yr-1 |
|  |  | Note: The use of the IPCC default factor 0.01 is recommended. |
| *Fracgas* | = | Fraction of managed livestock manure nitrogen that volatilizes as NH3 and NOx in the manure management phase; kg NH3-N and NOx-N emitted (Kg N)-1 |
| *GWPN2O* | *=* | Global warming potential for N2O (310 for the first commitment period); dimensionless |
| *44/28* | *=* | Conversion of N20-N emissions to N2O emissions |
| *0.001* | *=* | Conversion factor of kilograms into tonnes; dimensionless |
|  |  |  |

The best estimate of the annual nitrogen excretion rates for each livestock group is obtained using country-specific rates from published peer reviewed literature or from the national GHG inventory. If country-specific data cannot be collected or derived, or appropriate data are not available from another country with similar conditions, default nitrogen excretion rates can be obtained from table 10.19 of IPCC 2006 Guidelines for AFOLU.

The possible data sources for N2O emission factors are similar. Default emission factors are given in table 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU and default values for volatilization of NH3 and

NOx (Fracgas) in the manure management system are presented in table 10.22 of the same IPCC 2006 Guidelines. For EF4the IPCC default value 0.01 is recommended (equation 10.27, IPCC 2006 Guidelines for AFOLU).

## Step 4: Summation of emissions

Total emissions will be summed using the following equation:

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(12.6)

|  |  |  |
| --- | --- | --- |
|  | | |
| Where: |  |  |
| *El* | = | Emissions from livestock management; tonnes CO2e yr-1 |
| *ECH4,ferm* | *=* | CH4 emissions from enteric fermentation; tonnes CO2e yr-1 |
| *ECH4,manure* | *=* | CH4 emissions from manure management; tonnes CO2e yr-1 |
| *EN2O,manure* | *=* | N2O emissions from manure management; tonnes CO2e yr-1 |

# PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El,CH4,ferm* |
| Data unit: | tonnes CO2e yr-1 |
| Description: | CH4 emissions |
| Source of data: | Modeled from field data |
| Justification of choice of data or description of measurement methods and procedures applied: | CH4 emissions from enteric fermentation |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EF1* |
| Data unit: | kg CH4 head-1 yr-1 |
| Description: | Enteric CH4 emission factor |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Enteric CH4 emission factor for the livestock group |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Populationl* |
| Data unit: | # |
| Description: | Number of livestock |
| Source of data: | Data gathered using the module *TRS-9*  *Estimation of Domesticated Animal Populations* |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of livestock of a given livestock type |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *GWPCH4* |
| Data unit: | Dimensionless |
| Description: | Global warming potential for CH4 |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Global warming potential for CH4 (with a value of 21 for the first commitment period) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El,CH4,manure* |
| Data unit: | t CO2e yr-1 |
| Description: | CH4 emissions from manure management |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | CH4 emissions from manure management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EF2l* |
| Data unit: | kg *CH4* head-1 yr-1 |
| Description: | CH4 emission factor |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Manure management CH4 emission factor for the livestock group |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El,N2O,manure* |
| Data unit: | tonnes CO2e yr-1 |
| Description: | N2O emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | N2O emissions from manure management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El,Direct\_N2O,manure* |
| Data unit: | tonnes CO2e yr-1 |
| Description: | Direct N2O emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Direct N2O emissions from manure management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El,Indirect\_N2O,manure* |
| Data unit: | tonnes CO2e yr-1 |
| Description: | Indirect N2O emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Indirect N2O emissions from manure management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Nex* |
| Data unit: | kg N head-1 yr-1 |
| Description: | Annual average N excretion |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Annual average N excretion per livestock head |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EF3* |
| Data unit: | kg *N2O*-N (kg N-1) head-1 yr-1 |
| Description: | Emission factor for N2O emissions |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for N2O emissions from manure management for the livestock group |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EF4* |
| Data unit: | kg *N2O*-N (kg NH3-N and NOx-N emitted)-1 head-1 yr-1 |
| Description: | Emission factor for N2O emissions from atmospheric deposition |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for N2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Fracgas* |
| Data unit: | kg NH3-N and NOx-N emitted (Kg N)-1 |
| Description: | Fraction of managed livestock manure nitrogen |
| Source of data: | Peer reviewed literature, accepted variable values for national GHG inventories |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction of managed livestock manure nitrogen that volatilizes as NH3 and NOx in the manure management phase |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *GWPN2O* |
| Data unit: | Dimensionless |
| Description: | Global warming potential for N2O |
| Source of data: | IPCC (2006) Guidelines for national GHG inventories, Volume 4, Agriculture, forestry and other Land uses |
| Justification of choice of data or description of measurement methods and procedures applied: | Global warming potential for N2O (310 for the first commitment period) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *44/28* |
| Data unit: | Dimensionless |
| Description: | Conversion of N emissions to N2O emissions |
| Source of data: | Periodic table |
| Justification of choice of data or description of measurement methods and procedures applied: | Conversion of N emissions to N2O emissions |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El* |
| Data unit: | tonnes CO2e yr-1 |
| Description: | Emissions from livestock management |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from livestock management |
| Any comment: |  |

# REFERENCES AND OTHER INFORMATION

CDM methodology AR-AM 0004: Reforestation or afforestation of land currently under agricultural use. http://cdm.unfccc.int/methodologies/DB/S2OMSUTOWYOMLW75MPR0CG6SAKNG4Y (last visited 1909-2011)

CDM methodology AR-AM0006 version 3.1.1 Afforestation/Reforestation with Trees Supported by Shrubs on Degraded Land,

http://cdm.unfccc.int/UserManagement/FileStorage/T05CO1LWYIJ7EHD9GBVAKZPUSQ2N8X (last visited 19-09-2011)

IPCC. 2006. Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use

IPCC. 2000. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4, Agriculture.

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-11

ESTIMATION OF EMISSIONS OF NON-CO2 GHGs FROM SOILS

Version 1.1

14 January 2013 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## Table of Contents

[1 SOURCES 2](#_Toc66775)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc66776)

[3 DEFINITIONS 2](#_Toc66777)

[4 APPLICABILITY CONDITIONS 2](#_Toc66778)

[5 PROCEDURES 2](#_Toc66779)

[6 PARAMETERS 10](#_Toc66780)

[7 REFERENCES AND OTHER INFORMATION 20](#_Toc66781)

# SOURCES

CDM methodology *AR-AM0004 Reforestation or afforestation of land currently under agricultural use*.

Denitrification-decomposition process model (DNDC).

Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy, Nicolas Institute for Environmental Policy Solutions.

# SUMMARY DESCRIPTION OF THE MODULE

This module provides a suite of methods and approaches for estimating the emissions of CH4 and N2O from soils resulting from nitrogen inputs and soil processes.

# DEFINITIONS

**Emission Factor:** The average emission rate of a given pollutant for a given source, relative to the intensity of a specific activity.

**Significant:** A pool or source is significant if it does not meet the criteria for being deemed de minimus. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project.

# APPLICABILITY CONDITIONS

Applicable to projects where significant increases in the emissions of N2O or CH4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario.

# PROCEDURES

**Introduction:**

Soils and decaying organic material (including litter-fall in forests, fertilizers used on croplands, and manure stored in lagoons) can emit both methane and nitrous oxides, which are significant GHGs. This module is used to estimate the amounts of these GHGs emitted from the soil within the project area.

Emissions of methane and nitrogenous compounds from soils occur as a result of complex processes governed by both organic and inorganic variables.

Currently a number of different methods exist for the estimation of releases of methane and nitrogenous compounds into the atmosphere from soils. This module uses a hierarchical approach to the estimation of these releases, with more complete approximations of the processes and emissions used where larger emissions are expected. This hierarchy of methods is shown in the table below. Note that the ranges of expected emissions overlap for each method. The more complete model should be used where possible within these overlap ranges.

**Table 1:** Selection of methods

|  |  |  |
| --- | --- | --- |
| **Expected change in emissions of N compounds and CH4, measured in**  **CO2e, as a percentage of total project gross GHG benefit** | **Method** | **Typical Example** |
| 0 - 5% | IPCC[[15]](#footnote-17) | Dryland range restoration |
| 2 - 10% | DNDC  subset[[16]](#footnote-18) | Changes in tilled soil management including changes in fertilization practices |
| 5% + | DNDC[[17]](#footnote-19) | Changes in wetland management (rice cultivation, re-establishment of wetlands, drainage and tiling) Intensive use of organic amendments (manures, etc.) or fertilizers |

NOTE: When emissions of N2O from soils are being calculated, project proponents must ensure that emissions calculated under the manure management section of module *TRS-10 Estimation of Emissions from Domesticated Animals* are not also calculated here, as this would result in double counting.

If emissions of non-CO2 GHGs from soils is significant, this module must be used in conjunction with the module *TRS-2 Methods to Predict Future Conditions* to project soil GHG emissions under the baseline and project scenarios, and also must be used during the monitoring phase to estimate soil GHG emissions. When using this module to calculate baseline emissions, minimum baseline estimates for N2O and CH4 emissions must be based on documented management records averaged over the five year period prior to the project start date. Documented management records may include fertilizer purchase records, manure production estimates and/or livestock data. For new management entities or where such records are unavailable, minimum baseline estimates must be based on a conservative estimate of common practice in the region.

Application of the methods is undertaken using the following steps:

### Step 1: Document and map the following variables

* Amount, location, timing and conditions of applications of organic or inorganic fertilizers, and type of fertilizer applied.
* Amount, location and timing of areas subject to flooding, and duration of flooding
* Amount and location of nitrogen fixing species
* Soil conditions, temperature and moisture regimes
* Management activities

Note that if application of organic fertilizers is a direct result of grazing of domestic animals resident within the project area, calculations of emissions must be made using the module *TRS-10 Estimation of Emissions from Domesticated Animals*. Summation of net GHG change for those applications of organic fertilizers must not be accounted in this methodology, to avoid double counting.

### Step 2: Determine the method to be used

Estimate the percentage of changes in emissions resulting from emissions of CH4 and nitrous oxides, as a percentage of the total project GHG fluxes. This estimation can be undertaken using a wide variety of methods, including local knowledge or research, or a rough calculation using one of the methods outlined in Step 3 below. Document the methods used to arrive at this estimation. Based on the estimation, select the methods for calculating methane and nitrous oxide emissions.

### Step 3: Calculate the emissions of Methane and Nitrous Oxides

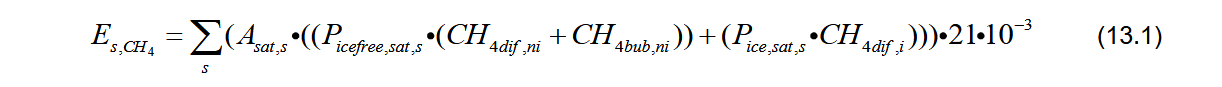
Based on the determination made in Step 2 above, use one of the following methods to calculate the emissions of CH4 and Ncompounds.

**Method 1:** IPCC methods

### Methane Emissions

Methane emissions occur principally due to the existence of anaerobic conditions in soils due to saturation and flooding. Methane emissions may also result from drainage practice changes in land use not involving flooding or saturation. However, availability of data on these changes is very limited, and changes from practice change in land use are largely expected to be small relative to total project fluxes. Thus this method calculates methane emissions only under conditions of flooding or saturation.

Methane emissions are calculated using the following equation:

**

(13.1)

|  |  |  |  |
| --- | --- | --- | --- |
| Where |  |  |  |
| *Es CH*, 4 |  | = | Total emissions of CH4 from the project area, t CO2e yr-1 in year t and strata s |
| *s* |  | = | Strata |
| *Asat s*, |  | = | The mean area of saturated soils in stratum s, ha |
| *Picefree sat s*, , |  | = | Period of during which the soil is saturated and ice free in stratum s, days |
| *CH*4*dif ni*, |  | = | The rate of emissions of CH4 by diffusion during ice free days, kg ha-1 day-1 |
| *CH*4*bub ni*, |  | = | The rate of emissions of CH4 by bubbling during ice free days, kg ha-1 day-1 |
| *Pice sat s*, , |  | = | Period during which the soil is saturated and ice covered in stratum s, days |
| *CH*4*dif i*, |  | = | The rate of emissions of CH4 by diffusion during ice covered days, kg ha-1day-1 |
| 21 10-3 |  | =  = | Global warming potential for CH4  Conversion from kilograms to tonnes |

Rates for emissions of methane must be drawn from local research. Where such research does not exist, the following default IPCC values may be used:

**Table 2:** Default emission values for CH4 **(**IPCC GPG LULUCF 2000 Table 14.3.1.1)

|  |  |  |  |
| --- | --- | --- | --- |
| **Ecosystem** | *CH*4*dif ni*, | *CH*4*bub ni*, | *CH*4*dif i*, |
| Boreal  Cold Temperate  Warm Temperate, dry  Warm Temperate, wet  Tropical, wet  Tropical, moist, long dry season  Tropical, moist, short dry season  Tropical, dry | kg/ha/day | kg/ha/day | kg/ha/day |
| 0.11 +/-88% | 0.29 +/-160% | 0.05 +/-60% |
| 0.2 +/-55% | 0.14 +/-70% |  |
| 0.063 +/-50% |  |  |
| 0.096 +/-77% |  |  |
| 0.64 +/-330% | 2.83 +/-45% |  |
| 0.31 +/-190% | 1.9 +/-155% |  |
| 0.44 +/-465% | 0.13 +/-135% |  |
| 0.3 +/-115% | 0.3 +/-324% |  |

Note that the range of variation for many of the default values is very high. Where project proponents choose to use a value other than the mean provided, they must justify the reason for the choice made, and demonstrate that it is conservative.

Where values do not exist for a given variable for the ecosystem in question, values from the most similar ecosystem must be substituted.

Definitions of the ecosystem types may be found in the Glossary of the IPCC GPG for LULUCF 2003 (IPCC 2003).

### Nitrous oxide emissions

The following method may only be used to determine nitrous oxide emissions where it can be shown that nitrogen application rates and the absorptive capacity of the soils is such that loss of nitrogen due to leaching or run-off is unlikely. Otherwise, Method 2, DNDC subset, must be used to estimate nitrous oxide emissions.

**Step A:** Monitoring and estimating the amount of nitrogen in synthetic and organic fertilizer used within the project area.

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(13.2)

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(13.3)

|  |  |  |
| --- | --- | --- |
| Where: | *s* |  |
| NSN-Fert,t | = | Total use of synthetic fertilizer within the project area, tonnes N yr-1 in year t |
| NON-Fert,t | = | Total use of organic fertilizer within the project area, tonnes N yr-1 in year t |
| As | = | Area of stratum s with fertilization, ha yr-1 |
| NSN-Fert,k,t | = | Use of synthetic fertilizer per unit area for stratum s, kg N ha-1 yr-1 in year t |
| NON-Fert,k,t | = | Use of organic fertilizer per unit area for stratum s, kg N ha-1 yr-1 in year t |
| 0.001 | = | Conversion kg N to tonnes N |

**Step B:** Choosing the fractions of synthetic and organic nitrogen fertilizer that is emitted as NOX and NH3, and emission factors.

As noted in GPG 2000 and 1996 IPCC Guidelines, the default emission factor is 1.25% of applied nitrogen, and this value must be used when country-specific factors are unavailable or project specific factors are not developed. Project proponents may develop specific emission factors that are more appropriate for their project. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000. The default values for the fractions of synthetic and organic fertilizer nitrogen that are emitted as NOX and NH3 are 0.1 and 0.2 respectively in 1996 IPCC Guideline[[18]](#footnote-20).

**Step C:** Calculating direct nitrous oxide emissions from nitrogen fertilization**[[19]](#footnote-21)**

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|  |  |  |
| --- | --- | --- |
| Where: |  |  |
| Es,N2O | = | The direct N2O emission as a result of nitrogen application within the project area during monitoring interval, tonnes CO2-e yr-1 in year t |
| FSN | = | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX, tonnes N yr-1 |
| FON | = | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX, tonnes N yr-1 |
| NSN-Fert | = | Amount of synthetic fertilizer nitrogen applied, tonnes N yr-1 |
| NSN-Fert | = | Amount of organic fertilizer nitrogen applied, tonnes N yr-1 |
| EF1 | = | Emission Factor for emissions from N inputs, tonnes N2O-N (tonnes N input)-1 |
| FracGASF = | | The fraction that volatilizes as NH3 and NOX for synthetic fertilizers, dimensionless |
| FracGASM = | | The fraction that volatilizes as NH3 and NOX for organic fertilizers, dimensionless |
| 44/28 = | | Ration of molecular weights of N2O and nitrogen, dimensionless |
| 310 = | | Global Warming Potential for N2O |

**Notes to application of the models or equations:**

* If organic fertilizers were applied, and those organic fertilizers arose from livestock and manure management practices already accounted in module *TRS-10 Estimation of Emissions from Domesticated Animals* Step 3, they must not be counted here, to avoid double counting.
* If organic fertilizers are applied on top of snow or frozen ground, it is difficult to be sure where or under what conditions the nitrogen in the fertilizer will interact with soils and plant communities. Therefore the nitrogen content of these fertilizers must conservatively be assumed to be 100% emitted as nitrous oxide.

If nitrogen fixing plants are present, nitrogen input from nitrogen fixing species will depend on the species, percent cover, and site conditions within which the plants are growing. For agronomic or other species where good data exists on the rates of nitrogen fixation, this data must be used to determine the amount of nitrogen input into the soils. For other species, where such data does not exist, data from known species must be used to determine the rate of nitrogen input. For non-woody species, for example, rates and conditions of nitrogen fixation by alfalfa may be used as a proxy for the nitrogen fixation of other species. In order to ensure conservatism, the percentage cover of the unknown species, as determined in the field, must be multiplied by 2, to a maximum of 100% cover, and the resulting cover number used to determine the expected fixation by alfalfa. Where such species with unknown rates of nitrogen fixation exist in quantities, project monitoring may include ongoing measurement of soil nitrogen, assist in the fine-tuning of future nitrogen fixation estimates for these species.

### Method 2: DNDC subset

Willey et al (2007) derived equations from the DNDC model. These equations take into account a largenumber of variables driving changes in the emissions of GHGs.

Use the equations in **Table 3** to estimate changes in methane emissions resulting from changes in:

* The duration of flooding and drainage during the growing season.
* The amount of time between manure application and flooding.
* The amount of carbon added to the soils as manure.
* The carbon content of the soil.
* The acidity (pH) of the soil.

Use the equations in **Table 4** to estimate change in nitrous oxide emissions resulting from changes in:

* The application rate of the nitrogen fertilizer.
* The application rate of carbon in the manure.
* The amount of organic carbon in the topsoil.
* The crop demand for nitrogen.
* The water input from precipitation and irrigation.
* The average annual air temperature.
* The clay content of the soil.
* The acidity (pH) of the soil.
* The land use (cropland, rice paddy, or grassland.) Note that the project area must be stratified according to land use in order to use this method.

**Table 3** - Equations derived from Results of DNDC Simulations to Estimate Methane Emissions from saturated Soils in the United States

A math equations and formulas

AI-generated content may be incorrect.

A screenshot of a computer

AI-generated content may be incorrect.

A screenshot of a math program

AI-generated content may be incorrect.**Table 4** Equations Derived from Results of DNDC Simulations to Estimate Nitrous Oxide Emissions from Soils in the United States.

### 

### Method 3: DNDC

Estimating methane and nitrous oxide emissions relies on the denitrification-decomposition process model, or DNDC (Li, Frolking, and Frolking 1992; Li, Narayanan, and Harriss 1996; Li, Aber, Stange, Butterbach-Bahl, and Papen 2000; and Li 2001). An example of the implementation of this approach is contained in the GHG Wizard version of DNDC. It uses data provided with the model on the weather, soil types, and crop types/acreage of each county in the United States, as well as user-specified data on fertilization, tillage, and other management practices for each crop rotation and year. The model uses this information to estimate changes in soil carbon, changes in methane and nitrous oxide emissions, and the global warming equivalents of these emissions. (See the DNDC website for the model, instructions on its use, and detailed discussions of its applications.) The model is supplied with source data for the United States, but can be used for other locations where source data can be provided.

Where DNDC is used it must be calibrated for the location and circumstances of the project.

If changes in emissions of methane and nitrous oxide are expected to constitute less than 50% of the total difference in estimated atmospheric GHGs between the baseline and project scenario, the DNDC model may be calibrated using existing local or regional time series data on soil emissions of methane and nitrous oxide, if such data exists. Otherwise, project proponents must collect their own calibration data. If changes in emissions of methane and nitrous oxide are expected to constitute 50% or more of the total difference in estimated atmospheric GHGs between the baseline and project scenarios, project proponents must collect local time series data covering the full annual cycle, and use that data to calibrate DNDC. In either case the uncertainty of the calibration data must be taken into account when determining the uncertainty deduction as described by the latest version of the VCS Standard. If the available time series data provides sufficient statistically tested data on emissions under different meteorological and management conditions for local soil conditions, it may also be possible to build a site specific model or customize another model and use this model in place of DNDC.

#### Step 4 : Summation of soil emissions

The total emissions from soils for a given year t will be summed using the following equation:

**

(13.7)

Where:

|  |  |  |
| --- | --- | --- |
| *Es*  *Es,CH4* | =  = | Total emissions from non-CO2 GHGs from soils for a given monitoring period, tCO2eyr-1  CH4 emission from the project area for a given monitoring period, tCO2e yr-1 |
| *Es,N2O* | = | N2O emission as a result of nitrogen application within the project area for a given monitoring period, tCO2-e yr-1 |

# PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *ES,CH4* |
| Data unit: | t CO2e yr-1 |
| Description: | Total methane emissions from project area |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total emissions of CH4 from the project area for a given monitoring period |
| Any comment: |  |
| **Data Unit / Parameter:** | *s* |
| Data unit: | Name |
| Description: | Strata |
| Source of data: | Assigned |
| Justification of choice of data or description of measurement methods and procedures applied: | Strata name |
| Any comment: |  |
| **Data Unit / Parameter:** | *Asat,s* |
| Data unit: | Hectares |
| Description: | Mean area of saturated soils |
| Source of data: | Field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The mean areas of saturated soils in stratum s |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Picefree, sat, s* |
| Data unit: | # |
| Description: | Period of during which the soil is saturated and ice free |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Days the soil of strata s is saturated and ice free |
| Any comment: |  |
| **Data Unit / Parameter:** | *CH4dif,ni* |
| Data unit: | kg ha-1 day-1 |
| Description: | Rate of emissions of CH4 by diffusion during ice free days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of CH4 by diffusion during ice free days |
| Any comment: |  |
| **Data Unit / Parameter:** | *CH4bub,ni* |
| Data unit: | kg ha-1 day-1 |
| Description: | Rate of emissions of CH4 by bubbling during ice free days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of CH4 by bubbling during ice free days |
| Any comment: |  |
| **Data Unit / Parameter:** | *Pice,sat,s* |
| Data unit: | kg ha-1 day-1 |
| Description: | Period during which the soil is saturated and ice covered in stratum |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Period during which the soil is saturated and ice covered in stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *CH4dif,i* |
| Data unit: | kg ha-1 day-1 |
| Description: | Rate of emissions of CH4 by diffusion during ice covered days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of CH4 by diffusion during ice covered days |
| Any comment: |  |
| **Data Unit / Parameter:** | *NSN-Fert,t* |
| Data unit: | tonnes N yr-1 in year t |
| Description: | Total use of synthetic fertilizer within the project area |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Total use of synthetic fertilizer within the project area |
| Any comment: |  |
| **Data Unit / Parameter:** | *NON-Fert,t* |
| Data unit: | tonnes N yr-1 in year t |
| Description: | Total use of organic fertilizer within the project area |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Total use of organic fertilizer within the project area |
| Any comment: |  |
| **Data Unit / Parameter:** | *Es,N2O* |
| Data unit: | tonnes |
| Description: | Direct N2O emissions as result of Nitrogen application |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The direct N2O emission as a result of nitrogen application within the project area during monitoring interval |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *As* |
| Data unit: | ha yr-1 |
| Description: | Area of stratum s with fertilization |
| Source of data: | Module *TRS-1 Methods to Determine*  *Stratification* |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |
| **Data Unit / Parameter:** | *FSN* |
| Data unit: |  |
| Description: | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX [1] |
| Source of data: | Calculated from field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX, |
| Any comment: |  |
| **Data Unit / Parameter:** | *FON* |
| Data unit: |  |
| Description: | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and  NOX |
| Source of data: | Calculated from field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and  NOX |
| Any comment: |  |
| **Data Unit / Parameter:** | *NSN-Fert* |
| Data unit: | tonnes N yr-1 |
| Description: | Amount of synthetic fertilizer nitrogen applied |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of synthetic fertilizer nitrogen applied |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *NSN-Fert* |
| Data unit: | tonnes N yr-1 |
| Description: | Amount of organic fertilizer nitrogen applied |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of organic fertilizer nitrogen applied |
| Any comment: |  |
| **Data Unit / Parameter:** | *EF1* |
| Data unit: | tonnes N2O-N (tonnes N input)-1 |
| Description: | Emission factor for emissions from N inputs, tonnes N2O-N |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for emissions from N inputs, tonnes N2O-N |
| Any comment: |  |
| **Data Unit / Parameter**: | *FracGASF* |
| Data unit: | Dimensionless |
| Description: | Fraction that volatilizes as NH3 and NO*X* for synthetic fertilizers |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The fraction that volatilizes as NH3 and NO*X* for synthetic fertilizers |
| Any comment: |  |
| **Data Unit / Parameter:** | *FracGASM* |
| Data unit: | Dimensionless |
| Description: | Fraction that volatilizes as NH*3* and NO*X* for organic fertilizers |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The fraction that volatilizes as NH3 and NO*X* for organic fertilizers |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *F* |
| Data unit: | # |
| Description: | Flooded days |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of days during which the site is flooded during the growing season |
| Any comment: |  |
| **Data Unit / Parameter:** | *clay* |
| Data unit: | Dimensionless |
| Description: | Soil clay fraction |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction of the total mass of the soil which is made up of clay |
| Any comment: |  |
| **Data Unit / Parameter:** | *A0-7* |
| Data unit: | # |
| Description: | Coefficient equation outputs |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Outputs of coefficient equations for the DNDC subset |
| Any comment: |  |
| **Data Unit / Parameter:** | *B0* |
| Data unit: | Coefficient |
| Description: | Constant |
| Source of data: | Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy ,  Nicolas Institute for Environmental Policy Solutions.p229 |
| Justification of choice of data or description of measurement methods and procedures applied: | Clay component constant for the DNDC subset equations |
| Any comment: |  |
| **Data Unit / Parameter:** | *D* |
| Data unit: | # |
| Description: | Drained days during the growing season |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *T* |
| Data unit: | ◦C |
| Description: | Mean annual temperature |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Mean annual air temperature |
| Any comment: |  |
| **Data Unit / Parameter:** | *PH* |
| Data unit: | pH |
| Description: | Soil pH |
| Source of data: | Laboratory testing of samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil pH |
| Any comment: |  |
| **Data Unit / Parameter:** | *MD* |
| Data unit: | # |
| Description: | Days of manure |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Days of manure amendment before start of flooding |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *MA* |
| Data unit: | kg manure – C/ha |
| Description: | Amount of manure |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of manure amended |
| Any comment: |  |
| **Data Unit / Parameter:** | *SOC* |
| Data unit: | kg C/kg soil |
| Description: | Soil organic carbon Content |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil organic carbon content |
| Any comment: |  |
| **Data Unit / Parameter:** | *LEAK* |
| Data unit: | mm/day |
| Description: | Soil Water leaking rate |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil water leaking rate |
| Any comment: |  |
| **Data Unit / Parameter:** | *Y* |
| Data unit: | kg C/ha/growing season |
| Description: | Crop yield |
| Source of data: | Crop data |
| Justification of choice of data or description of measurement methods and procedures applied: | Crop yield |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Rf n* |
| Data unit: | kg N/ha/yr |
| Description: | Fertilizer application rate |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Fertilizer application rate |
| Any comment: |  |
| **Data Unit / Parameter:** | *A0-3* |
| Data unit: | kg N/ha/yr |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Background N20 flux coefficients for the N20 equations in the DNDC subset |
| Any comment: |  |
| **Data Unit / Parameter:** | *B1-2* |
| Data unit: | kg N/ha/yr |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Saturated N20 flux coefficients for the N20 equations in the DNDC subset |
| Any comment: |  |
| **Data Unit / Parameter:** | *K0-7* |
| Data unit: | Rate coefficients |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated rate coefficients for N emissions in the DNDC subset |
| Any comment: |  |
| **Data Unit / Parameter:** | *C* |
| Data unit: | kg C/kg soil |
| Description: | SOC content in top soil |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | SOC content in top soil (top 15 cm of the soil) |
| Any comment: |  |
| **Data Unit / Parameter:** | *CN* |
| Data unit: | kg N/ha |
| Description: | Crop demand for N |
| Source of data: | Standard site specific agricultural N demand calculation based on laboratory results from soil samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Crop demand for N |
| Any comment: |  |
| **Data Unit / Parameter:** | *P* |
| Data unit: | mm |
| Description: | Total annual precipitation |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Total annual precipitation |
| Any comment: |  |
| **Data Unit / Parameter:** | *LU* |
| Data unit: | # |
| Description: | Land-use type |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Land-use type category (cropland: 1, rice paddy: 2, grassland: 3) |
| Any comment: |  |

# REFERENCES AND OTHER INFORMATION

Li et al., 1992a. A model of nitrous oxide evolution from soil driven by rainfall events: 1. Model structure and sensitivity. Journal of Geophysical Research 97:9759 9776

Li et al., 1996, Model estimates of nitrous oxide emissions from agricultural lands in the United States, Global Biogeochemical Cycles 10:297-306

Li et al., 2000. A process-oriented model of N2O and NO emissions from forest soils: 1, Model development, J. Geophys. Res. 105:4369-4384

[Li, 2001. Biogeochemical concepts and methodologies: Development of the DNDC model. Quaternary Sciences 21:89-99 (in Chinese with English abstract)](http://www.dndc.sr.unh.edu/papers/Li_biogeochemistry.pdf)

Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental Policy Solutions

IPCC. 1996. Revised guidelines for National GHG inventories (http://www.ipccnggip.iges.or.jp/public/gl/invs1.html last visited 14-09-2011)

IPCC. 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4, Agriculture.

IPCC. 2006. Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |
| V1.1 | 14 Jan 2013 | Corrections to certain coefficient equations and definitions used in the DNDC subset method have been incorporated |

TRS-12

ESTIMATION OF EMISSIONS FROM POWER EQUIPMENT

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

# Table of Contents

1. SOURCES ............................................................................................................................................. 2
2. SUMMARY DESCRIPTION OF THE MODULE ................................................................................... 2
3. DEFINITIONS........................................................................................................................................ 2
4. APPLICABILITY CONDITIONS ............................................................................................................ 2
5. PROCEDURES ..................................................................................................................................... 2
6. PARAMETERS...................................................................................................................................... 3
7. REFERENCES AND OTHER INFORMATION ..................................................................................... 5

**1 SOURCES**

CDM methodology *AR-AM0004 Reforestation or afforestation of land currently under agricultural use*

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides the equations, references and constants needed to calculate emissions of GHGs from power equipment used for project activities both within and outside of the project area.

|  |  |
| --- | --- |
| **3 DEFINITIONS** |  |
| **Directly Attributable:** | The change or effect occurs as result of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be primarily and directly caused by the previous event in the chain. Analysis of the linkages in the chain should show that for each one, the previous event is at least 75% responsible for the next event. For this reason, the relationship between an event, or the actions of an agent, and the directly attributable effect, typically consist of not more than a few causal linkages. |
| **Emission Factor:** | The average emission rate of a given pollutant for a given source, relative to the intensity of a specific activity. |
| **Power Equipment:** | Equipment or tool powered by a combustion engine running on fossil fuels including vehicles. |

**4 APPLICABILITY CONDITIONS**

None

# 5 PROCEDURES

GHG emissions may occur as a result of activities either within or outside of the project area due to burning of fossil fuels in powered equipment used for treatments, management, transportation of supplies.

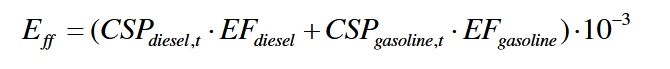
**Step 1:** Monitor and/or estimate the type and amount of fossil fuels consumed in activities directly attributable to the project activity.

When this module is used in an ex-post situation (under project conditions, or baseline conditions in the case of a monitored baseline) the amounts of fuels used must be tracked on an ongoing basis based on fuel invoicing. If invoicing does not provide complete information, fuel use may be estimated based on average fuel use per hour or distance traveled for a given piece of machinery.

Under ex-ante conditions, the amounts of fuels used by type must be estimated using the module *TRS-2 Methods to Project Future Conditions*.

**Step 2:** Choose the most appropriate emission factors. There are three possible sources of emission factors:

* Regional emission factors;
* National emission factors: These emission factors developed by national programs such as national GHG inventory;
* IPCC default emission factors provided that a careful review of the consistency of these factors with the country conditions has been made. IPCC default factors may only be used when no other information is available.

****Step 3:** Estimate GHG emissions resulting from the burning of fossil fuel during activities directly attributable to the project activity. Although some non-CO2 GHG (CO, CH4, NMVOCs) may be released during combustion process, all the released carbon are accounted as CO2 emissions based on the Revised 1996 IPCC Guidelines for energy:

(14.1)

Where:

Eff = Emissions from the burning of fossil fuels, tCO2 yr-1

CSPdiesel,t = Amount of diesel consumption, liter (l) yr-1 in year t

CSPgasoline,t = Amount of gasoline consumption, l yr-1 in year t

EFdiesel = Emission factor for diesel, kg CO2 l-1

EFgasoline = Emission factor for gasoline, kg CO2 l-1

10-3 = Conversion kg to tonnes

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Eff* |
| Data unit: | kg CO2/year |
| Description: | Estimated GHG emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Estimated GHG from fuel burning |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *CSPdiesel,* |
| Data unit: | Liter (l) |
| Description: | Amount of diesel consumption |
| Source of data: | Inventory of diesel consumption (ex-post), or estimation of diesel consumption using the module *TRS-2 Methods to Project Future Conditions* (ex-ante). |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of diesel consumption |
| Any comment: |  |
| **Data Unit / Parameter:** | *CSPgasoline,* |
| Data unit: | Liter (l) |
| Description: | Amount of gasoline consumption (ex-post) or estimation of future gasoline consumption using the module *TRS-2 Methods to Project Future Conditions* (ex-ante) |
| Source of data: | Inventory of fuel use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of gasoline consumption |
| Any comment: |  |
| **Data Unit / Parameter:** | *EFdiesel* |
| Data unit: | kg CO2 l-1 |
| Description: | Emission factor for diesel |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for diesel |
| Any comment: |  |
| **Data Unit / Parameter:** | *EFgasoline* |
| Data unit: | kg CO2 l-1 |
| Description: | Emission factor for gasoline |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for gasoline |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

UNFCCC, EB50. CDM AR-AM0004 Reforestation or afforestation of land currently under agricultural use http://cdm.unfccc.int/UserManagement/FileStorage/KYBDLQFMI6R20X58OGH3Z71N9TSU4A (Last visited 13-09-2011).

IPCC. 1996. Revised Guidelines for National Greenhouse Gas Inventories, http://www.ipccnggip.iges.or.jp/public/gl/invs1.html (Last visited 14-09-2011).

# DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-13

ESTIMATION OF EMISSIONS FROM BIOMASS BURNING

Version 1.0

16 November 2012

Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

1. SOURCES ............................................................................................................................................. 2
2. SUMMARY DESCRIPTION OF THE MODULE .................................................................................... 2
3. DEFINITIONS ........................................................................................................................................ 2
4. APPLICABILITY CONDITIONS ............................................................................................................. 2
5. PROCEDURES ...................................................................................................................................... 2
6. PARAMETERS .................................................................................................................................... 15
7. REFERENCES AND OTHER INFORMATION .................................................................................... 24

**1 SOURCES**

VCS methodology, *VM0015 Methodology for Avoided Unplanned Deforestation, v1.0*

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides methods for estimating non-CO2 emissions from burning biomass.

|  |  |
| --- | --- |
| **3 DEFINITIONS** |  |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project. |
| **Canopy Surface:** | Area covered with vegetation canopy. |
| **Conservative:** | Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables. |

**4 APPLICABILITY CONDITIONS**

None

# 5 PROCEDURES

**Introduction:**

Burning, whether anthropogenic or natural, results in CO2 and non-CO2 emissions from both woody and non-woody vegetation, and litter. CO2 emissions are accounted as changes in accounted carbon pools using modules *VMD0021 Estimation of Stocks in the Soil Carbon Pool*, *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*, *TRS-5 Estimation of Carbon Stocks in the Litter Pool*, and *TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool*. This module accounts for non-CO2 emissions from biomass burning. Note that in this module, emissions from burning under the baseline scenario are only accounted if:

* Burning would be a result of planned, controlled burns; and
* The conditions (temperature, humidity, fuel moisture content, windspeed, etc.) under which burning would take place are prescribed, and sufficient ecosystem-specific information exists to forecast the amount of fuel that would be consumed under these conditions.

Otherwise, emissions from burning under the baseline scenario must be conservatively accounted as 0.

Two basic approaches can be used to calculate the non-CO2 emissions from fire:

**Approach A:** Generic calculations using IPCC default values; or

**Approach B:** Calculations based on inventories of biomass consumed.

Note that if Approach A is used, the project proponent must provide sufficient evidence to demonstrate that the calculations produce conservative results.

**Approach A:** IPCC Default Values

Approach A uses consumption factors and emission factors from the IPCC GPG LULUCF to estimate the emissions of non-CO2 GHGs (CH4 and N2O). The emissions are calculated separately for CH4 and for N2O using the following equation for both calculations:

*A black and white text

AI-generated content may be incorrect.*

(15.1)

Where:

|  |  |  |
| --- | --- | --- |
| *LFire* | = | The quantity ofGHGs emitted, tonnes. |
| *Aburn* | = | Area burnt, hectares. |
| *BC* | = | Amount of biomass consumed, from Table 15.1 below (IPCC GPG for LULUCF Table 3A.1.13), tonnes/hectare. |
| *EF* | = | Emission factor for the GHG being calculated, from Table 15.2 below (IPCC GPG for LULUCF Table 3A.1.16), g/kg, equivalent to kg/tonnes. |

|  |  |  |  |
| --- | --- | --- | --- |
| Table 15.1- Part 1  Biomass consumption (t/ha) values for fires in a range of vegetation types  IPCC GPG for LULUCF Table 3A.1.13 or the most recent versions published by IPCC | | |  |
| **Vegetation type** | **Sub category** | **Mean** | **SE** |
| Tropical Forest (slash and burn | Primary tropical forest | 83.9 | 25.8 |
| Primary open tropical forest | 163.6 | 52.1 |
| Primary tropical moist forest | 160.4 | 11.8 |
| Primary tropical dry forest | - | - |
| All primary tropical forest | | 119.6 | 50.7 |
| Secondary tropical forest (slash and burn) | Young secondary tropical forest (3-5 yrs) | 8.1 | - |
| Intermediate secondary tropical forest (6-10 yrs) | 41.1 | 27.4 |
| Advanced secondary tropical forest (14-17 yrs) | 46.4 | 8.0 |
| All secondary tropical forest | | 42.2 | 23.6 |
| All tertiary tropical forest | | 54.1 | - |
| Boreal Forest | Wildfire (general) | 52.8 | 48.4 |
| Crown fire | 25.1 | 7.9 |
| Surface fire | 21.6 | 25.1 |
| Post logging slash burn | 69.6 | 44.8 |
| Land clearing fire | 87.5 | 35.0 |
| All boreal Forest | | 41.0 | 36.5 |
| Eucalypt forest | Wildfire | 53.0 | 53.6 |
| Prescribed fire- (surface) | 16.0 | 13.7 |
| Post logging slash burn | 168.4 | 168.8 |
| Felled and burned (land clearing fire) | 132.6 | - |
| All eucalypt Forest | | 69.4 | 100.8 |
| Other temperate forests | Wildfire | 19.8 | 6.3 |
| Post logging slash burn | 77.5 | 65.0 |
| Felled and burned (land clearing fire) | 48.4 | 62.7 |
| All “other” temperate forests | | 50.4 | 53.7 |
| Shrublands | Shrubland (general) | 26.7 | 4.2 |
| *Calluna* Heath | 11.5 | 4.3 |
| Sagebrush | 5.7 | 3.8 |
| Fynbos | 12.9 | 0.1 |
| All shrublands | | 14.3 | 9.0 |

|  |  |  |  |
| --- | --- | --- | --- |
| Table 15.1- Part 2  Biomass consumption (t/ha) values for fires in a range of vegetation types  IPCC GPG for LULUCF Table 3A.1.13 or the most recent versions published by IPCC | | | |
| **Vegetation type** | **Sub category** | **Mean** | **SE** |
| Savannah Woodlands (mid/late dry season burns | Savannah woodland | 2.5 | - |
| Savannah parkland | 2.7 | - |
| All savannah woodlands (early dry season burns) | | 2.6 | 0.1 |
| Savannah Woodlands (mid/late dry season burns) | Savannah woodlands | 3.3 |  |
| Savannah parkland | 4.0 | 1.1 |
| Tropical Savannah | 6 | 1.8 |
| Other savannah woodlands | 5.3 | 1.7 |
| All savannah woodlands (mid/late dry season burns) | | 4.6 | 1.5 |
| Savannah  Grasslands/Pastures (mid/late dry season burns) | Tropical /sub-tropical grassland | 2.1 | - |
| Grassland | - | - |
| All savannah grasslands (early dry season burns) | | 2.1 |  |
| Savannah grasslands/pastures (mid/late dry season burns) | Tropical/subtropical grasslands | 5.2 | 1.7 |
| Grasslands | 4.1 | 3.1 |
| Tropical pasture | 23.7 | 11.8 |
| Savannah | 7.0 | 2.7 |
| All savannah grasslands(mid/late dry season burns) | | 10.0 | 10.1 |
| Other vegetation Types | Peatland | 41 | 1.4 |
| Tundra | 10 |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 15.2  Emission Factors (g/kg dry matter combusted) applicable to fuel combusted in various types if vegetation fires.  IPCC GPG for LULUCF Table 3A.1.16 or the most recent versions published by IPCC | | | | | | |
|  | **CO2** | **CO** | **CH4** | **NOx** | **N2O\*** | **NMHC2** |
| Moist/infertile broadleaved savannah | 1523 | 92 | 3 | 6 | 0.11 |  |
| Arid fertile fine-leaved savannah | 1524 | 73 | 2 | 5 | 0.11 |  |
| Moist infertile grassland | 1498 | 59 | 2 | 4 | 0.1 |  |
| Arid-fertile grassland | 1540 | 97 | 3 | 7 | 0.11 |  |
| Wetland | 1554 | 58 | 2 | 4 | 0.11 |  |
| All vegetation types1 | 1404-  1503 | 67-120 | 4-7 | 0.5-0.8 | 0.10 |  |
| Forest Fires | 1531 | 112 | 7.1 | 0.6-0.8 | 0.11 | 8-12 |
| Savannah Fires | 1612 | 152 | 10.8 |  | 0.11 |  |
| Forest Fires | 1580 | 130 | 9 | 0.7 | 0.11 | 10 |
| Savannah Fires | 1640 | 65 | 2.4 | 3.1 | 0.15 | 3.1 |
| 1  Assuming 41-45% C content, 85-100% combustion completeness  2  NMHC = non methane hydro carbons  \*  calculated from data of Crutzen and Andrea (1990) assuming an N/C ratio of 0.01, except for savannah fires. | | | | | | |

**Approach B:** Estimation of Emissions Based on Biomass Inventories

This approach consists of two steps:

**Step 1: Determine the amount of biomass consumed by the fire**

Most of the biomass consumed in a fire consists of fine fuels (litter, non-woody vegetation, leaves and twigs on woody vegetation). However, some course woody materials, both living and dead may also be consumed. Where superficial organic soil horizons exist, some part of these may also be consumed. The equation for determining the total amount of biomass consumed is therefore:

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AI-generated content may be incorrect.* (15.2)

|  |  |  |
| --- | --- | --- |
| Where: |  |  |
| Bburn | = | The amount of biomass burned, t |
| OSburn | = | The amount of organic soil burnt, t |
| Bdwburn | = | The amount of course woody debris burnt, t |
| WBburn | = | The amount of living woody biomass burnt, t |
| Bsmburn | = | The amount of small woody and non-woody vegetation burnt, t |
| Blburn | = | The amount of litter burnt, t |

The steps for each of these pools are as follows:

**Step 1a: Litter**

Accounting for litter must be undertaken using the methods contained in the module *TRS-5 Estimation of Carbon Stocks in the Litter Pool*. After a fire event, the methods contained in that module must be used to estimate the residual litter biomass in the burned portion of each stratum impacted by the fire. Where the litter biomass of the stratum was estimated using the methods in the module *TRS-5 Estimation of Carbon Stocks in the Litter Pool* prior to the fire event, that number will be used for *Bls pre*,  in equation 15.3.

Where no litter plots existed in the area prior to burning, estimations of the litter pool prior to the fire must be generated based on information gathered from comparable sites outside of the burned area using the methods outlined in module *TRS-5 Estimation of carbon tocks in the Litter Pool*. Comparable sites must be determined based on:

* Evidence found in existing photos which give some evidence of the amount and size distribution of litter before the fire;
* Similarity of ecosystem, and disturbance and management history; and/or
* Local knowledge.

Where this approach is used, the methods given in the module *TRS-5 Estimation of Carbon Stocks in the Litter Pool* must be used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore *Asburn* = *As* in equation 15.3.

The amount of litter consumed by the fire is therefore:

*A black and white text

AI-generated content may be incorrect.*

(15.3)

*s*

Where:

|  |  |
| --- | --- |
| *Blburn* | *=* The total biomass of litter burnt, t |
| s | = Strata |
| *Asburn* | = The area burnt in stratum s, ha |
| *As* | = The total area of stratum s, ha |
| *Bls pre*, | = Litter biomass in stratum s prior to the fire, t |
| *Bls post*, | = Litter biomass in the burnt area of stratum s after the fire, t |

**Step 1b: Small woody and Non-woody vegetation**

Estimation of amounts of small woody and non-woody vegetation prior to and after burning are determined using the methods outlined in module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*. The breakpoint between small and large woody vegetation must be determined prior to the fire event during initial sampling of biomass in the ecosystem. After a fire event, the methods contained in that module must be used to estimate the residual small woody and non-woody biomass in the burned portion of each stratum impacted by the fire. Where the small woody and non-woody biomass of the stratum was estimated using the methods in the module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass* prior to the fire event, that number will be used for *Bsms pre*,  in equation 15.4.

Where no small woody and non-woody plots existed in the area prior to burning, estimations of the small woody and non-woody pool prior to the fire must be generated based on information gathered from comparable sites outside of the burned area using the methods outlined in the module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*. Comparable sites must be determined based on:

* Evidence found in existing photos which give some evidence of the amount and size distribution of litter before the fire;
* Similarity of ecosystem, and disturbance and management history; and/or  Local knowledge.

Where this approach is used, the methods given in the module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass* are used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore *Asburn* = *As* in equation 15.4.

The amount of non-woody vegetation consumed by the fire is therefore:

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AI-generated content may be incorrect.*

(15.4)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Where: | | *s* | |  |
| *Bsmburn* | | = | | The amount of small woody and non-woody vegetation burnt, t |
| *Asburn* | | = | | The area of the portion of the stratum which burnt, hectares |
| *As* | | = | | The area of the stratum, hectares |
| *Bsms pre*, | | = | The dry weight of small woody and non-woody vegetation in stratum s before the fire, t | |
| *Bsms pre*, | | = | The dry weight of small woody and non-woody vegetation in the burnt area of | |

stratum s after the fire, t

**Step 1c: Large woody vegetation**

Determining the amount of large woody vegetation consumed by a fire can be complex, as amounts can vary considerably depending on the intensity of the fire. For a given fire intensity, the amount of available fuel of this type will depend on the number, size and type of large woody plants present on the site. As well, the percentage of combustion will vary depending on the fuel size and position. Note that while large woody vegetation will typically be defined as woody individuals with a stem size above some minimum diameter or height cut-off, these individuals will also have many branches and twigs smaller than the cutoff, which will also be accounted as part of the large woody vegetation. The project proponent may propose and justify their own technique for estimating this fuel fraction, or use the following approach:

Fine fuels (leaves and twigs) make up the majority of the living biomass combusted, even in fairly intense fires. However, the amount of this fuel, as well as the amount of stem wood and large branches consumed, will vary from fire to fire, based on fire conditions, the size and type of living tissues present, and other factors. The method outlined in the steps below allows specific estimation of the amounts of fuel combusted. Since non-CO2 emissions are largely associated with the combustion of volatile gasses, fuels reduced entirely to char (for instance, charcoal remnants of branches) are accounted as having been fully combusted for the purposes of this module.

The project proponent must use the following steps:

**Step 1c-1: Estimate the amount of biomass present before the fire.**

Determine the total amount of large woody above ground biomass present within the burned area prior to the fire using the methods given in the module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*. Where inventories already exist, and where a fire has not burned the entire area of a stratum, the amount of biomass present within the burned area of a stratum is calculated using the following equation:

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(15.5)

*s*

Where:

|  |  |  |
| --- | --- | --- |
|  |  |  |
| *BABb* | = | Total aboveground large woody biomass in the burned area of the stratum before the fire, t |
| *BABs* | = | Total aboveground large woody biomass in stratum s before the fire, t |
| s | = | Stratum |
| *Aburn s*, | = | Area burned within stratum s by the fire, ha |
| *As* | = | Total area of stratum s, ha |

Note that where the “Census from Remote Sensing” method is used to determine large woody biomass, *BABs* may not be directly available. In this case, *BABs* must be derived from Bws using the following equation:

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AI-generated content may be incorrect.*

(15.6)

|  |  |  |
| --- | --- | --- |
| Where |  |  |
| *BABs* | = | Total aboveground large woody biomass in the stratum before the fire, t |
| Bws | = | Total large woody biomass in the stratum before the fire, t |
| R | = | Root to shoot ratio, dimensionless |

**Step 1c-2: Determine the large woody vegetation types present in the burned area.**

Woody vegetation types are classes of species, sizes, or other variables on which the fire had similar impacts. For instance, one vegetation type might consist of all large shrubs and small trees less than 6 m tall, another group might consist of isolated fire resistant trees greater than 6 m tall, and another type might consist of densely stocked areas of trees greater than 6 m tall where crown fire occurred. Document the definition of each woody vegetation type, and undertake each of the following steps for each of the types.

**Step 1c-3: Determine the fuels consumed.**

After the fire, sample each different woody vegetation type (species, species group, size group, or other grouping) to determine the average size class of the fine biomass consumed in areas of the canopy which were burned. Biomass will be conservatively counted as consumed when more than 50% of the cross-sectional area of the twig or branch is missing or consists of char. Thus for example, for a given species group, it may be determined that on average branches less than 1 cm in diameter were consumed.

**Step 1c-4: Determine the percentage of canopy surfaceconsumed.**

Depending on the nature of the fire (ground fire, canopy fire, etc.), the fire may have consumed biomass throughout the canopy, or only in the lower sections. Through observation and/or sampling, determine the average percentage of the canopy surface consumed by fire for each species or species group.

**Step 1c-5: Determine the amount of fuel per unit of canopy surface.**

Sampling from unburned areas, determine the amount of biomass per unit area which falls into the burnt size class for each species or species group. This should be done by clipping all the biomass at or below the burnt size class within a specified area (a 1 m square, for example), drying and weighing it. Samples must be taken across the range of canopy locations where fire consumption occurred, since the amount of fine biomass may vary by canopy position. The total of all samples taken must be averaged to determine the amount of biomass burnt per unit of canopy surface. Determine the relationship between canopy surface and a known woody vegetation inventory variable such as DBH.

*A math symbols with a plus and a plus

AI-generated content may be incorrect.*Canopy surface for a given tree may be approximated using the following equation which describes a simplified shape of a cylinder (with a height of (*ch-r) and radius of r* and a radius and with half a sphere (with a radius of r):

(15.7)

Where:

*CA* = Canopy surface, m2

*r* = Average radius of the canopy (distance from the point of germination to the drip line), m

*ch* = Height of the canopy from the lowest branch to the top of the living crown., m

For each woody vegetation type, the proponent must derive values for r and ch. These values must be averages across the type. However, they must be calculated using a derived relationship from known variable found in the woody vegetation inventory data, such as height, basal area, or other variables.

**Step 1c-6: Using pre-fire inventory data, calculate the total canopy surface per hectare for each woody vegetation type.**

If a derived relationship is calculated in Step 1c-4, above, divide the average woody vegetation population within the woody vegetation type into classes (*k*) based on the range of values of the determining variable used. Thus, for instance if a relationship has been derived between *r* and *ch* and the height of the tree, divide the inventory for the woody species type being calculated into classes of tree heights. Determine the average number of trees per hectare for each class from the inventory. Calculate total canopy surface (which describes a simplified shape of a cylinder (with a height of (*ch-r)* and radius of r and a radius and with half a sphere (with a radius of r)):for the woody vegetation type using the following equations:

*A black and white math equation

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(15.8)

Where:

*j*  = The woody vegetation type *k* = The class of the determining variable (canopy size class, height, or some other variable)

*x*  = The number of different classes of the determining variable *TCAj* = The total canopy surfacefor woody vegetation type j, m2/ha *pkj* = The population of the woody plants falling into class k for type j, #/ha *rkj* = The average radius of the crown for woody plants falling into class k for type j, m

*chkj* = The average canopy height for woody plants falling into class k for type j, m

**Step 1c-7: Calculate the total biomass consumed.**

Use the following equation:

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Where:

*j*  = The woody vegetation type

*y*  = The number of different types of woody vegetation

*WBburn =* The total largewoody plant biomass consumed

*Aburn* = Area burnt, hectares

*TCAj* = The total canopy surface for woody vegetation type j, m2/ha

C%j = The percentage of canopy surface which was burned, m2/m2

Bburn,j  = The amount of biomass consumed per unit of canopy surface burned, kg/m2

**Step 1c-8: Check the total biomass consumed against the total pre-fire above ground biomass.**

Where *WBburn* is within the margin of error for Bws at a 90% confidence interval, for the stratum within which the fire occurred, as determined in Part A Step 5 of the module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*, no further checking is required. Where the burned area crosses more than one stratum, with differing confidence intervals, average confidence interval must be derived weighted by the percentage of the total burn area represented by the burned area within each stratum.

Where more substantial portions of the aboveground biomass have been consumed, check to ensure that *WBburn* as a percentage of *BABb* is reasonable. Checking may be undertaken though calculation of non-stem wood above ground biomass before the fire from *BABb* using a biomass expansion factor, and destructive sampling of residual non-stem wood above-ground biomass in the burned area, to confirm that:

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AI-generated content may be incorrect.*

(15.10)

|  |  |
| --- | --- |
| Where |  |
| *WBburn* | *=* The total largewoody plant biomass consumed, t |
| *BABns postfire*, | *=* Residual non-stem biomass in the burned area, t |
| *BABb* | = Total aboveground large woody biomass in the burned area of the stratum before the fire, t |
| BEF | = Biomass Expansion Factor, dimensionless |
|  | = The difference between the right and left sides of the equation falls within the margin of error of Bws at a 90% confidence interval, for the burned portion of the stratum, as determined in Part A, step 5 of the |

module *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*. Where the burned area crosses more than one stratum, with differing confidence intervals, total confidence interval must be derived weighted by the percentage of the total burned area represented by the burned area within each stratum.

**Step 1d: Dead wood**

Dead wood consumption must be calculated using module *TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool*, and subtracting post-fire dead wood biomass from pre-fire dead wood biomass, with the following modification. The radius of each piece measured will be considered to be the outer radius less the distance to which the point of a sharp knife can by sunk into the piece of wood with moderate pressure, when oriented across the grain, which will be used as a measure of the char layer.

Where pre-fire inventories of dead wood exist for the burnt area, these may be used directly for the prefire inventory. Where no such inventories exist, two options may be used to estimate pre-fire inventories:

**Option A:** Where fire consumption mostly consists of superficial charring.

In many cases, broadcast burning of distributed fuels will only result in surface charring. In these cases, the average outside diameter of the each piece measured on the transect line must be considered to be the pre-fire diameter of the piece. Because all of the charred material is considered to be fully consumed, this approach is conservative despite the fact that it may miss some small amount of pre-fire cross sectional area.

Note that this method may not work in the case of repeated fires, where some of the charred area detected may have resulted from previous fires. However, in such cases inventories should exist from the period immediately after the previous fire, and these must be used for the pre-fire case.

**Option B:** Where significant consumption of fuels has occurred.

For windrowed and similar materials significant consumption of fuels may occur. In most cases such burning will be deliberate, and a pre-fire inventory must have been completed. However, if no such inventory exists, similar fuel accumulations in unburned areas (proxy areas) must be inventoried using the methods outlined in module *TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool* to provide an estimate of the conditions before the fire in the burnt area. Proxy areas must be selected based on similarity to the conditions found in the burn area before the fire in terms of amount of dead wood and dead wood piece size distribution. Since using the proxy area implies that no good quantitative inventory of dead wood within the burn area existed prior to the fire, similarity must be judged based on qualitative factors, including:

* Evidence found in existing photos which give some evidence of the amount and size distribution of dead wood before the fire;
* Similarity of ecosystem, and disturbance and management history; and/or  Local knowledge.

If the burn area does not completely cover a pre-existing ecosystem, disturbance and management history stratum, residual unburnt areas of the stratum may be the best candidate for use as a proxy area, providing that there is no reason to suspect that the boundary of the burn area was determined by differences in dead wood density, piece size, or distribution.

Where no pre-fire inventory exists for the stratum, and where Option A or B are used, the methods given in module *TRS-6 Estimation of Emissions of Biomass Burning* must be used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore *Asburn*  *As* in equation 15.11.

The total amount of dead wood burnt in stratum *s* is calculated by the following equation:

*A black text with a dot and a black circle

AI-generated content may be incorrect.* (15.11)

|  |  |
| --- | --- |
| Where: |  |
| *Bdwburn* | = The amount of dead wood burnt in the fire, t |
| *s* | = Strata |
| *Asburn* | = The area burnt in stratum s, ha |

*As* = The total area of stratum s, ha

*Bdws pre*,  = Total dead wood biomass in stratum s prior to the fire, t

*Bdws post*,  = Total dead wood biomass in the burnt area of stratum s after the fire, t

**Step [[20]](#footnote-22)e: Organic Soil**

Where organic soil layers are consumed by fire, the amount of soil biomass consumed is calculated by the following equation:

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | (15.12) |
| Where: |  |  |
| *OSburn* | *=* | The amount of organic soil burned*,* t |  |
| *Aburn* | *=* | Area burnt, hectares |  |
| *Db* | *=* | The average depth of the soil burnt,cm |  |
| *OSm -* | *=* | The mass of the organic soil, kg/m3 |  |

**Step 2: Estimating of GHG emissions resulted from the biomass consumption by fire based on revised IPCC 1996 Guideline for LULUCF and GPG LULUCF.**

Non-CO2 emissions resulting from biomass consumption by fire will be estimated using the following equations:

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AI-generated content may be incorrect.* (15.13)

|  |  |  |
| --- | --- | --- |
| 2 4 | | |
| Where: |  |  |
| Eb | = | Non-CO2 emission as a result of biomass burning, tonnes CO2-e |
| EBiomassBurn, N2O | = | N2O emission from biomass burning in slash and burn, tonnes CO2-e |
| EBiomassBurn, CH4 | = | CH4 emission from biomass burning in slash and burn, tonnes CO2-e |

A group of black text

AI-generated content may be incorrect. (15.14)

(15.15)

Where1:

BBurn = Amount of biomass consumed in the fire, t

*EFN O*2 = Emission factor for N2O from Table 17.2 (IPCC GPG LULUCF Table 3A.1.16)

*EFCH*4 = Emission factor for CH4 from Table 17.2 (IPCC GPG LULUCF Table 3A.1.16)

310 = Global Warming Potential for N2O

21 = Global Warming Potential for CH4

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *LFire* |
| Data unit: | Tonnes |
| Description: | Emitted GHG due to Fire |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The quantity of GHG emitted, in units of CO2e, due to fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *As* |
| Data unit: | Ha |
| Description: | Area of the stratum |
| Source of data: | Field surveys or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | Area of the stratum |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Aburn* |
| Data unit: | Ha |
| Description: | Area burnt |
| Source of data: | Field surveys or remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | Area burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *BC* |
| Data unit: | Tonnes/hectare |
| Description: | Amount of biomass consumed |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of biomass consumed by fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EF* |
| Data unit: | g/kg, equivalent to kg/tonnes |
| Description: | Emission factor |
| Source of data: | IPCC GPG for LULUCF Table 3A.1.16 |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for the GHG being calculated (CO2, N2O, CH4) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bburn* |
| Data unit: | Tonnes |
| Description: | Amount of biomass burned |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of biomass burned |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *OSburn* |
| Data unit: | Tonnes |
| Description: | Amount of organic soil burnt |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of organic soil burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bdwburn* |
| Data unit: | Tonnes |
| Description: | Amount of dead wood burnt |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | the amount of dead wood burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *WBburn* |
| Data unit: | Tonnes |
| Description: | Amount of living woody biomass burnt |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of living woody biomass burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bsmburn* |
| Data unit: | Tonnes |
| Description: | Amount of small woody and non-woody vegetation burnt |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of small woody and non-woody vegetation burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Blburn* |
| Data unit: | Tonnes |
| Description: | Amount of litter burnt |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of litter burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bls,pre* |
| Data unit: | t |
| Description: | Dry weight of litter in stratum s before the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Dry weight of litter in stratum s before the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bls,post* |
| Data unit: | t |
| Description: | Dry weight of litter in the burnt area in stratum s after the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Dry weight of litter in the burnt area in stratum s after the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Asburn* |
| Data unit: | ha |
| Description: | Area burnt in stratum s |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Area burnt in stratum s |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bsms,pre* |
| Data unit: | t |
| Description: | The dry weight of small woody and non-woody vegetation in stratum s before the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The dry weight of small woody and non-woody vegetation in stratum s before the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bsms,post* |
| Data unit: | t |
| Description: | The dry weight of small woody and non-woody vegetation in the burnt area of stratum s after the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The dry weight of small woody and non-woody vegetation in the burnt area of stratum s after the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *CA* |
| Data unit: | m2 |
| Description: | Canopy surface |
| Source of data: | Estimated from remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | Canopy surface |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *r* |
| Data unit: | m |
| Description: | Average radius of the canopy |
| Source of data: | Calculated from remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | Average radius of the canopy (distance from the point of germination to the drip line) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *ch* |
| Data unit: | m |
| Description: | Height of the canopy |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Height of the canopy from the lowest branch to the top of the living crown |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *TCAj* |
| Data unit: | m2/ha |
| Description: | Total canopy surface |
| Source of data: | Estimated from remote sensing |
| Justification of choice of data or description of measurement methods and procedures applied: | The total canopy surface for woody vegetation type j, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *pkj* |
| Data unit: | #/ha |
| Description: | Population of the woody plants |
| Source of data: | Estimated from remote sensing and confirmed by field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | the population of the woody plants falling into size class k for type j, |
| Any comment: |  |
| **Data Unit / Parameter:** | *rkj* |
| Data unit: | m |
| Description: | Average radius of the crown for woody plants |
| Source of data: | Remote sensing or field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | the average radius of the crown for woody plants falling into size class k for type j, |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *chkj* |
| Data unit: | m |
| Description: | Average canopy height for woody plants |
| Source of data: | Remote sensing or field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The average canopy height for woody plants falling into size class k for type j |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *j* |
| Data unit: | Dimensionless |
| Description: | Woody vegetation type |
| Source of data: | Field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The woody vegetation type class determined by stratification based on fire impact. |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *k* |
| Data unit: | Dimensionless |
| Description: | Class of the determining variable |
| Source of data: | Remote sensing or field sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | The class of the determining variable (canopy size class, height, or some other variable) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *x* |
| Data unit: | # |
| Description: | Number of different classes of the determining variable |
| Source of data: | Remote sensing or field sampling |
| Justification of choice of data or description of measurement methods and procedures applied: | The number of different classes of the determining variable (canopy size class, height, or some other variable) |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *WBburn* |
| Data unit: | Tonnes |
| Description: | Total woody plant biomass consumed |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The total woody plant biomass consumed |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *C%j* |
| Data unit: | % |
| Description: | Percentage of canopy surface which was burned |
| Source of data: | Estimated from remote sensing or field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The percentage of canopy surface which was burned |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bburn,j* |
| Data unit: | kg/m2 |
| Description: | Amount of biomass consumed per unit of canopy surface burned |
| Source of data: | Calculated from field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The amount of biomass consumed per unit of canopy surface burned |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bdws,pre* |
| Data unit: | t |
| Description: | Total dead wood biomass in stratum s prior to the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Total dead wood biomass in stratum s prior to the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bdws,post* |
| Data unit: | t |
| Description: | Total dead wood biomass in the burnt area of stratum s after the fire |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | Total dead wood biomass in the burnt area of stratum s after the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Db* |
| Data unit: | cm |
| Description: | Average depth of the soil burnt |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average depth of the soil burnt |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *OSm* |
| Data unit: | kg/m3 |
| Description: | Mass of the organic soil |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The mass of the organic soil |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Eb* |
| Data unit: | Tonnes CO2-e |
| Description: | Non-CO2 emission as a result of biomass burning, |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The Non-CO2 emission as a result of biomass burning, tonnes CO2-e |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EBiomassBurn, N2O* |
| Data unit: | Tonnes CO2-e |
| Description: | N2O emission from biomass burning |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | N2O emission from biomass burning in slash and burn, tonnes CO2-e |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EBiomassBurn, CH4* |
| Data unit: | tonnes CO2-e |
| Description: | CH4 emission from biomass burning |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | CH4 emission from biomass burning in slash and burn |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *BBurn* |
| Data unit: | t |
| Description: | Amount of biomass consumed in the fire |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of biomass consumed in the fire |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EFN2O* |
| Data unit: | # |
| Description: | Emission factor for N2O |
| Source of data: | Table 17.2: IPCC GPG LULUCF Table 3A.1.16 |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for N2O |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *EFCH4* |
| Data unit: | # |
| Description: | Emission factor for CH4 |
| Source of data: | Table 17.2: IPCC GPG LULUCF - Table 3A.1.16 |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for CH4 |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *310* |
| Data unit: | # |
| Description: | Global Warming Potential for N2O |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Global Warming Potential for N2O |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *21* |
| Data unit: | # |
| Description: | Global Warming Potential for CH4 |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Global Warming Potential for CH4 |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

IPCC. 1996. Revised Guidelines for National Greenhouse Gas Inventories, http://www.ipccnggip.iges.or.jp/public/gl/invs1.html (Last visited 14-09-2011).

VCS methodology, *Methodology for Avoided Unplanned Deforestation VM0015, v1.0*

# DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-14

ESTIMATION OF EMISSIONS FROM ACTIVITY-SHIFTING LEAKAGE

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 2](#_Toc20103)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc20104)

[3 DEFINITIONS 2](#_Toc20105)

[4 APPLICABILITY CONDITIONS 2](#_Toc20106)

[5 PROCEDURES 3](#_Toc20107)

[6 PARAMETERS 8](#_Toc20108)

[7 REFERENCES AND OTHER INFORMATION 9](#_Toc20109)

# 1 SOURCES

VCS methodology, *VM0015 Methodology for Avoided Unplanned Deforestation*[[21]](#footnote-23)

CDM methodology, *AR-AM 0004 Reforestation or afforestation of land currently under agricultural use*.[[22]](#footnote-24)

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides two possible approaches to the estimation of emissions resulting from activityshifting to areas outside of the project area, resulting in the emission of GHGs from carbon pools.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Agent:** | A person or organization undertaking actions which impact the management of carbon pools and emissions. |
| **Leakage Zone:** | Zone in which leakage is expected to occur and must therefore be monitored. |
| **Project Area:** | The area of land on which the project proponent will undertake project activities. |
| **Reasonably Attributable:** | The change or effect occurs as result of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be caused by the previous event in the chain with a probability greater than 50%. |
| **Significant:** | A pool or source is significant if it does not meet the criteria for being deemed *de minimis*. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

**Introduction:**

Only leakage which results in changes in carbon pools or carbon emissions from specific areas outside of the project areaare assessed using this module. Thus, for instance, market leakage, where emissions may result from changes in price or other market signals caused by implementation of the project, but where the physical location of the emissions cannot be identified, is not estimated using this module. This module also does not account for emissions from power equipment outside the project area, since those emissions are accounted in the module *TRS-12 Estimation of Emissions from Power Equipment*.

This module provides methods to estimate emissions due to activity-shifting leakage under the project scenario. It is possible that some similar changes (for instance movement of populations to other areas, clearance by local actors of areas outside the project area, etc.) might also have occurred under the baseline scenario, due to causes not associated with the project. In such cases, these changes under the baseline scenario must be projected using the module *TRS-2 Methods to Project Future Conditions*, and deducted from those found using the methods in this module.

This module provides two possible approaches to identifying the amount of project areaactivity-shifting:

**Approach A:** Tracking a sample of agents who are undertaking activities within the project area under the baseline scenario, to determine if those activities are shifted to areas outside of the project area under the project scenario.

**Approach B:** Tracking of changes in land management in an area surrounding the project area (the leakage zone) to see if changes occur in carbon pools which are reasonably attributable to activity-shifting from within the project area.

Approach A is required unless the project proponent can demonstrate that, due to the size of the project or other factors, Approach A is not feasible.

Once the nature and amount of activity-shifting has been determined using one of these two approaches, the amount of GHG emissions associated with this leakage are estimated.

Note that a shift of activity from within the project area to outside of the project area does not necessarily result in leakage. For instance, if cattle are shifted from within the project area to outside of the project area, without any significant change in carbon pools outside of the project area, and emissions from domesticated animals are not included as part of the project area, leakage has probably not occurred. On the other hand, if trees are cleared to provide enhanced pasture for these cattle, or if significant losses of soil carbon are reasonably attributable to the presence of the cattle outside the project area, then leakage has probably occurred.

### Step 1: Determine the approach used to identify activity-shifting leakage

Determine whether Approach A or Approach B is to be used to identify and quantify activity-shifting leakage. As noted above, Approach A is required and Approach B is to be used only where the project proponent can demonstrate that, due to the size of the project or other factors.

**Step 2: Quantify emissions**

### Approach A: Tracking of agents

If Approach A was selected in Step 1, activity-shifting leakage must be monitored through sampling the households and communities whose activities have been displaced from land by the project.

Monitoring is undertaken over a 5 year period, as effects arising more than 5 years after the

commencement of a project activity are unlikely to meet the standards for being reasonably attributable to the project activity. Thus, under this method, leakage due to conversion of land is not attributable to the project activity if the conversion of land occurs 5 or more years after the shifting of the activity to areas outside the project area. However, where leakage begins during the 5 year period, and is expected to continue (for instance, loss of soil carbon due to overgrazing of areas outside of the project area by cattle displaced from the project area), ongoing monitoring of leakage events identified during the first 5 year period must continue in subsequent monitoring periods.

Under this approach, activity-shifting leakage estimation includes monitoring agents who are undertaking identifiable actions leading to leakage, and conservatively estimating the leakage arising from agents who are not monitored, based on the data generated by the monitoring.

The type and schedule of measures to be taken to prevent leakage must be described in the VCS project description and their implementation monitored.

Leakage due to shifting of agricultural activities can be set as zero (LKconv-area = 0) where activities are shifted to land area with a carbon stock equal to or less than the land from which they are displaced:

CSb ≥ CSAD (16.1)

Where:

CSb = Carbon stock of baseline (t CO2eq ha-1)

CSAD = Locally derived carbon stock (including all 5 measurement pools; t CO2eq ha-1) of area of land on which activities shifted.

In such cases, activities are expected to be unlikely to result in further losses of carbon stocks in areas which were at least as degraded as the project area prior to the displacement occurring.

**Before project start date, undertake steps A.1 and A.2**

### Step A.1: Identification of agents and activities

Identify the types of activities occurring both within the project area, and in the surrounding areas, and the types of agents undertaking these activities.

Note that an agent may be an individual, a business or corporation, a family, a cooperative, or any other type of organization where decisions are made by a single person, or collectively or hierarchically by some or all of the members of the organization.

### Step A.2: Quantification of agents, activities and landbase

Step A.2-a:

Identify and record the number and identity of agents occupying or undertaking activities on land inside the project area, and determine the amount of land occupied by each agent. Randomly select 10% of the agents (or a minimum of 30) to be sampled for each type of activity undertaken. Where fewer than 30 agents are undertaking activities within the project area, all of them must be tracked.

Step A.2-b:

Identify and estimate the amount of each activity type undertaken by each sampled agent within the project area.

Step A.2-c

Identify and estimate the amount of all land based activities currently undertaken outside the project area by the sampled agents.

**One year after project start date, undertake step A.3**

### Step A.3: Monitoring of agent activities

One year after the project start date, record activities undertaken by the agents outside the project area using the following steps:

Step A.3-a:

Classify sampled agents as either having identifiable or unidentifiable activities outside of the project area. Agents who have moved outside of the province, state, or similar administrative boundary within which the project occurs or who cannot be found are categorized as ‘unidentifiable agents’.

Step A.3-b:

For identifiable agents, measure or sample, and estimate the amount of each type of activity that the agent is undertaking both inside and outside of the project area. Measure or sample using the appropriate module for the type of activity being undertaken.

Step A.3-c:

Determine whether an increase in each type of activity outside the project area by each agent has occurred by subtracting the amount of the activity estimated in Step A.2-c from the amount of activity occurring outside the project area estimated in Step A.3-b. Determine whether a decrease in the amount of the activity by the agent within the project area has occurred by subtracting the amount determined for that area in Step A.2-b from the amount determined in Step A.3-b. For any type of activity for which an increase in the amount of the activity outside of the project area by the agent has occurred, and a decrease in that activity by that agent has occurred within the project area, continue to Step A.3-d.

Step A.3-d

For each case where increased activity by an agent outside of the project area is detected, and the agent has reduced the amount of that activity being undertaken within the project area, determine whether or not the activity is having a negative impact on existing carbon pools outside of the project area , or is causing an increase in emissions of non-CO2 GHGs from the soil or biomass outside the project area , or an increase in non-CO2 GHGs from enteric fermentation.

Note that as specified in the module *TRS-10 Estimation of Emissions from Domesticated Animals*, where project activities result in a net lower emissions from domesticated animals (ie, emissions from domesticated animals both within and outside the project area), as compared with the baseline, the project proponent can conservatively choose not to account for emissions from domesticated animals under the baseline and project scenarios. In this case, leakage arising from emissions from domesticated animals would also not be accounted.

However, reductions in soil carbon pools in areas outside of the project area resulting from the increased domesticated animal populations would still constitute leakage.

Step A.3-e

For each activity shift causing leakage, locate and map the area impacted by the shifted activity, or quantify the source of the emissions outside of the project area, where it is not area specific (for instance, enteric emissions from cattle outside of the project area).

Step A.3-f:

Determine the nature of the impact caused by the activity-shifting. For instance, activity-shifting might result in decreased woody biomass on an area, decreased soil carbon, increased emissions of CH4 and N2O from soils, enteric fermentation, etc.

Step A.3-g:

Utilize the appropriate sampling and calculation modules to conservatively determine the GHG emissions resulting from the activity-shifting leakage. Note that for soil carbon and other similar pools, quantification of the pools at time t=0 in the area affected by the activity-shifting may not exist. However, subsequent monitoring undertaken in Step A.4 will allow estimation of changes between time t=1 and t=5, and changes can be extrapolated backward to time t=0 using appropriate models and assumptions.

Step A.3-h

For sampled agents who are currently unidentifiable, identify the type and amount of activity which they undertook prior to project commencement. Estimate the amount of emissions attributable to them based on extrapolation of the results from the identifiable agents undertaking that activity, proportional to the amount of the activity that they were undertaking. Similarly, in cases where more than 30 agents existed, and not all agents were sampled, extrapolate the results from the sampled agents to the total population of agents proportionally to the amount of the activity undertaken prior to the commencement of the project.

In the case that all of the agents who formerly undertook a particular activity within the project area prior to project commencement (for instance, cattle grazing) are unidentifiable, leakage attributable to those agents must conservatively be calculated based on the assumption that all of the agents continued to undertake the same amount of the activity outside of the project area. Emissions from this displaced activity must be calculated based on the method most likely to be used by people with the economic capacity and skill set of the displaced agents. For example, if smallholders undertaking swidden (slash and burn) agriculture were displaced, the assumption must be that they will continue to undertake swidden agriculture, and the amount of GHGs released by these activities must reflect the soil and vegetation conditions most likely to be found in land which would be available to them.

**5 years after project start date, undertake Steps A.4 and A.5**

### Step A.4: Final monitoring

Repeat Steps A.3-a through A.3-h to determine whether further sources of leakage have arisen, and to quantify the amount of such leakage. For sources of leakage which were identified in Step A.3, Steps A.3-e through A.3-h must be repeated.

### Step A.5: Continued impacts of activity shifting

Where leakage sources identified in Steps A.3 or A.4 are expected to continue, project the quantity of leakage expected to occur during each future monitoring period using the module *TRS-2 Methods to Project Future Conditions*.

### Approach B: Leakage zone

If the project proponent can demonstrate that, due to the size of the project, or other factors, Approach A is not feasible, the use of this Approach B is appropriate and the following steps must be undertaken:

**Before the project start date, undertake Steps B.1 and B.2.**

### Step B.1:Locate the leakage zone

The leakage zone is an area surrounding the project area, within which leakage is expected to be likely to occur for a given form of leakage.

The project proponent must identify the leakage zone geographically. The project proponent must provide documentation of the reasons for believing that the chosen leakage zone reasonably captures the area within which most of the leakage would be expected to occur.

### Step B.2:Prepare the baseline for the variable within the leakage zone

The baseline for the variable(s) which might be impacted by leakage must be projected for the entire area of the leakage zone for the project crediting period using the module *TRS-2 Methods to Project Future Conditions*. Utilization of the module *TRS-2 Methods to Project Future Conditions* must include the use of Step 13 to identify changes in the variable on a location specific basis.

**5 years after the project start date, undertake Steps 3.3, 3.4 and 3.5.**

### Step B.3:Determine the current status of the variable within the leakage zone

The current status of the variable within the leakage zone must be determined using the appropriate methods given in the module relevant to the variable. Where direct sampling of the variable is not possible, remote sensing methods described in Step 7 of the module *TRS-2 Methods to Project Future Conditions* may be used. In this case, remote sensing images should not be more than 1 year old.

### Step B.4:Correct the baseline for changes in exogenous factors

When the future values of the variable were projected for the baseline using the module *TRS-2 Methods to Project Future Conditions*, an analysis of the projected future values and impacts of drivers, agents and causes found to be significant was undertaken. Since the analysis of leakage using this approach is undertaken on an ex-post basis, estimates of the actual values of those significant drivers, agents and causes must be ascertained. If those values differ significantly from those used in the ex-ante projections, and that change has occurred as a result of exogenous causes, not as a result of the implementation of the project, the baseline projections of the variable for the leakage zone must be revised based on the estimated actual values of the drivers, agents and causes. For instance, it may have been expected that population in the leakage zone would increase slightly as a result of displacement of a few families from the project area. If in fact the population in the leakage zone has doubled due to immigration of people from another part of the country, the baseline will need to be recalculated to account for the part of the change in population which was not caused by the project activity.

### Step B.5:Determine if leakage has occurred

The following decision sequence must be used to determine if leakage has occurred:

Step B.5-a: Reduction of carbon pools, and/or increase in GHG emissions

If the current values of the variable indicate that less carbon exists in carbon pools within the leakage zone, and/or that there has been an increase in GHG emissions, as compared with the amounts that were forecast using the revised baseline for the leakage zone, prepared in Step 3.4 above, continue to Step 3.5.b. If not, no leakage has occurred.

Step B.5-b: Presence of previously unidentified drivers, agents or causes

Determine whether any other exogenous driver, agent or cause, not identified ex-ante, may account for the change in the variable. If the project proponent can demonstrate and document that, with a high degree of probability, such a factor is responsible for the change in the variable, and the consequent reduction in carbon pools and/or increase in GHG emissions within the leakage zone, then no leakage has occurred. If not, then continue to Step 3.5.c. For instance, a change in the world market price for a key agricultural commodity may not have been modeled in the baseline, because it was unlikely that the price change would be large enough to be significant. Since the commencement of the project activity, however, the price of that commodity has tripled, and as a result large areas of land within the leakage zone have been cleared to grow the commodity by large agricultural operators. If the project proponent can demonstrate that all significant change in carbon stocks in the leakage zone is attributable to this change, then it is reasonable to conclude that no significant and attributable leakage has occurred.

Step B.5-c: Plausible causal chain

If the project proponent can demonstrate, with a high degree of probability, that no plausible causal linkage or chain could exist between the actions of the project and the reduction of carbon pools, and/or increase in GHG emissions found, then no accountable leakage has occurred. Otherwise, leakage has occurred.

### Step 3: Quantify the change in emissions arising from activity-shifting leakage

If activity-shifting leakage has been found to be reasonably attributable to the project, and significant, using the methods in Approach A or Approach B, then the amount of activity-shifting leakage that has occurred is calculated using the following equation:

*A black text with a white background

AI-generated content may be incorrect.*

(16.2)

Where:

|  |  |  |
| --- | --- | --- |
| Ed | = | The emissions arising from activity-shifting, tCO2e |
| Cpb | = | The total carbon content of the affected pools under the baseline scenario, as modified in Step 3.4, tCO2e |
| Cpp | = | The total carbon content of the affected pools under the project scenario, tCO2e |

Carbon content of the pools affected must be estimated or projected using the appropriate modules and methods for that pool, as well as the module *TRS-2 Methods to Project Future Conditions* where projections are required.

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *CSb* |
| Data unit: | tCO2e.ha-1 |
| Description: | Carbon stock of baseline per hectare |
| Source of data: | Estimated using appropriate modules |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *CSAD* |
| Data unit: | tCO2e.ha-1 |
| Description: | Locally derived carbon stock (including all 5 measurement pools; t CO2eq ha-1) of area of land on which activities shifted |
| Source of data: | Estimated using appropriate modules |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Ed* |
| Data unit: | tCO2e |
| Description: | Emissions arising from activity-shifting |
| Source of data: | See formula 15.2 |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |
| **Data Unit / Parameter:** | *Cpb* |
| Data unit: | tCO2e |
| Description: | The total carbon content of the affected pools under the baseline scenario, as modified in Step 3.4 |
| Source of data: | Field survey |
| Justification of choice of data or description of measurement methods and procedures applied: | The average diameter of the piece of dead wood at the line |
| Any comment: |  |
| **Data Unit / Parameter:** | *Cpp* |
| Data unit: | tCO2e |
| Description: | The total carbon content of the affected pools under the project scenario |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

None

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-15

ESTIMATION OF EMISSIONS FROM MARKET LEAKAGE

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

## Table of Contents

[1 SOURCES 2](#_Toc15681)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc15682)

[3 DEFINITIONS 2](#_Toc15683)

[4 APPLICABILITY CONDITIONS 2](#_Toc15684)

[5 PROCEDURES 2](#_Toc15685)

[6 PARAMETERS 8](#_Toc15686)

[7 REFERENCES AND OTHER INFORMATION 8](#_Toc15687)

# 1 SOURCES

None

# 2 SUMMARY DESCRIPTION OF THE MODULE

The module provides methods for estimating whether reductions in the production of commodities (such as wood, animals or agricultural products) resulting from the project activity is likely to result in increased emissions from the production of those products elsewhere, and provides methods for determining the volume of such emissions.

# 3 DEFINITIONS

|  |  |
| --- | --- |
| **Project Activity:** | See *VCS Program Definitions.* |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |

# 4 APPLICABILITY CONDITIONS

None

# 5 PROCEDURES

### Step 1: Identification of commodities and services

Identify all commodities or services whose supply may be reduced on a local, regional, national or international scale due to implementation of the project activity. These commodities and services must include any commodity or service which meets the following criteria:

* Prior to project commencement the commodity or service was produced within the project area, and;
* The commodity or service was not produced solely for the producer`s use, but was sold or bartered to others (it was a market commodity or service), and;
* The commodity or service provided more than 5% of the total cash and barter income earned by residents within the project area.

Data for this step may be derived from:

* Existing statistical data,
* Economic studies,
* Market studies, or
* Oral testimony, including Participatory Rural Appraisals

Identify the current markets for the products or services, in terms of the percentage of the product produced within the project area going to local, regional, national and international markets, and the scale of each of those markets, in product units (e.g. kg), and record in the following table:

### Table 1: Market and product table

|  |  |  |
| --- | --- | --- |
| **Market** | **Product 1 – (%)** | **Product 1 – Market scale (units/yr)** |
| Local (within the community or communities immediately surrounding the project area) |  |  |
| Regional (within the province/s or other generally recognized region/s containing the project) |  |  |
| National (within the country, or in some cases, within the group of countries, where close economic integration exists, containing the project) |  |  |
| International (worldwide) |  |  |
| Total | 100% |  |

Information on markets will typically be best derived using interviews with producers, combined where necessary with interviews with market intermediaries to determine the final destination of the product or service, where the producer is not sure. This information may be supplemented with information from existing studies or existing statistical databases.

### Step 2: Barrier analysis

For each of the markets for each individual products or services, determine the barriers surrounding that market. Barriers may consist of distribution costs, tariff or regulatory barriers, or other circumstances which tend to reduce the introduction of the goods or services from markets at the next scale/s up (for instance introduction of a product from the provincial or national market to the local market), or from neighboring markets of the same scale (for instance from the next town, the next province). Grade these barriers on the following scale:

### Table 2: Barrier grades

|  |  |
| --- | --- |
| Grade | Description |
| Low | Products or services are readily substituted from markets at the next scale/s up, or from neighboring markets at the same scale. For instance, no significantbarriers exist to bringing the product or service into the local market from the regional or national market (price differences less than 5% more expensive, no other barriers). |
| Medium | Barriers do exist, but their effects are limited to price differentials for goods or services from markets at the next scales up or from neighboring markets. Goods brought from neighboring markets or markets at the next scale up are not more than 15% more expensive than those currently available in the market. For instance, fruit from another province can be brought to the local area with a price premium of about 10%. |
| High | Significantbarriers exist. Products or services cannot be brought from markets at the next scale up or neighboring markets, or are significantly more expensive (greater than 15% more) due to transport costs, tariffs, or for other reasons. |

Where existing information on market barriers does not exist in statistical databases or previous studies, interviews with market participants, producers, and/or intermediaries may be the best source of this information. Market participants may have in depth knowledge of the nature and degree of barriers to marketing of specific products.

### Step 3: Re-assessment of markets

Recalculate the market percentages, beginning with the local market and working up. For each product or service:

* If the barriers between that market and the next market are low, add that market percentage to the next market up. For example, if the product sells 20% to the local market and 80% to the regional market, but the barriers between the local and regional markets are low, the market for the product should be recalculated as 100% regional.
* If the barriers between that market and the next market are medium, move 50% of the market percentage to the next market up. For example, if the product sells 20% to the local market and 80% to the regional market, but the barriers between the local and regional markets are medium, the markets for the product should be recalculated as 10% local and 90% regional.
* If the barriers between that market and the next market up are high, no recalculation need be undertaken.

### Step 4: Percentage of the market supplied

Multiply the revised market percentages by the total amount of that product or service provided from the project areaprior to the project start date. For each market which the project supplies, calculate the percentage of the total market which the project supplies.

Example: The project area produces 10,000 kilograms of oranges per year. These oranges are sold 10% to the local market, and 90% to the regional market. The barriers between the local, and regional and national markets are low, but there are high barriers between the national and international markets. The revised market percentage for the oranges is thus 100% to the national market. The total national market for oranges is 500,000 kilograms. Thus the project area supplies 2% of the national market.

Data on total markets for a given product are typically best found in government or institutional databases. Some information may also be found in existing studies, and market participants, particularly larger scale intermediaries, may also have significant knowledge on this. At times local or regional scale data may have to be inferred from national data, using appropriate methods, such as weighting by population.

### Step 5: Market significance

If for a given product the project supplies less than 3% of the total market in each market that it supplies, go to Step 10. If the project supplies more than 3% of any given market, proceed to Step 6.

### Step 6: Replacement paths

For each product market, for which the project areasupplies more than 3% of the total market volume of that product, determine the least cost replacement path. Paths to be examined include:

* Replacement by production from higher scale markets, with additional costs resulting from the barriers between markets.
* Replacement by existing alternate items within the market area.
* Increased production within the market area.

Assess the cost increase resulting from each of these replacement paths.

Typically market participants, particularly medium and large scale intermediaries, will have an excellent idea of the most likely replacement paths. Local producers are likely to have a good idea of the cost barriers to increased production within the local market area.

Select the replacement path which gives the lowest cost increase.

* If this path is replacement by existing alternate items, calculate the percentage of the market for the alternate items represented by the substitution, and return to Step 4.
* If the path is replacement by production in a higher scale market, recalculate the percentage of the product going to the higher level market as the sum of the percentage going to the current market and the percentage going to the higher level market, and return to Step 4.
* If the path is increased production within the market area, proceed to Step 7.

### Step 7: Market impact

Assess the market impact of the replacement path.

* Estimate the expected price of the commodity or service required to allow increased production within the market area. This estimation must be based on an analysis of the least cost route to increased production. For instance, increased production of cattle might be achieved through production intensification, using more grain feeding to increase the number of cattle per unit area, or it might be achieved by increasing the amount of area used for cattle. Each of these options will have a cost associated with it – either the cost of increased feed purchases, or the cost of adding pasture. This method assumes that the cattle rancher will increase the production of cattle using whichever method adds the least costs per animal produced.

Once the least cost route to increased production is determined, the expected price of the commodity or service required to allow this production will be the new cost of production, plus the typical overhead coverage and profit margin for this commodity or service, which is usually best determined through interviews with local producers of the commodity.

* + If this price is less than 5% greater than the current market price, increase of production of this commodity or service from other providers within the market area is expected to be equal to 100% of the reduction caused by the project. Proceed to Step 8.
  + If this price is more than 5% greater than the current market price, quantify the expected impact of the increased price on consumption of the commodity or service. Analysis must include the impacts of product substitution, reductions in use, and changes in the use of discretionary income.

* Based on this analysis, quantify the expected actual increase in production of the commodity or service in the market area from sources outside of the project area*.*

**Example 1:**

The project area currently produces 10,000 kilos of oranges a year, all going to the local market. High transportation costs mean that there are significant barriers between the local and regional markets. Farmers in the local area would readily produce more oranges if they could find a market, by increasing fertilization rates in the orange orchards, even at the same price. Therefore, when orange production is stopped in the project area, other farmers in the local market area are expected to readily increase their production by 10,000 kilos of oranges a year to replace the lost production.

**Example 2:**

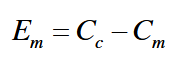
As above, the project area produces 10,000 kilos of oranges a year, all going to the local market, and high transportation costs mean that there are significant barriers between the local and regional markets. However, the current price for oranges in the local market is resulting in farmers getting out of orange production. The price would have to be 20% higher to incentivize farmers to grow more oranges. A price increase of this magnitude would result in many people no longer buying oranges, or buying fewer. The result would be that an estimated 7,000 kilos less oranges would be consumed per year. Thus, the most likely increase in orange production as a result of the project activity is 3,000 kilos.

### Step 8: Land impact

Identify the area of land required to produce the amount of product or service identified in Step 7, and the most probable land base on which this production will take place. For this land base, identify the probable management regime required to commence and continue production (eg, clearing tropical forests and planting of orange orchards).

### Step 9: Carbon impact

Using sampling, modeling and widely accepted values, quantify the total carbon stocks on the identified land base under the management regime present in the baseline scenario (ie, the management regime that existed before market leakage effects occurred), and model the projected carbon stocks on the land base under the management regime required to produce the product or service in the project scenario (ie, the management regime in the project scenario caused by the market leakage). Carbon impact of market leakage will be calculated using the following equation:



(17.1)

Where:

|  |  |  |
| --- | --- | --- |
| *Em* | = | Market leakage, t CO2e |
| *Cc* | = | Carbon stocks of the identified land base under the management regime present in the baseline scenario, tCO2e |
| *Cm* | = | Carbon stocks of the identified land base under the management regime expected to result from the market leakage in the project scenario, tCO2e |

The methods and models used to complete this stage must be those defined in the modules associated with VCS methodology *VM0021 Soil Carbon Quantification Methodology*, for the relevant carbon pools. The change in onsite carbon stocks through time between the management regime before and after market leakage occurred, on the affected land, is the leakage attributable to the project. Changes in offsite GHG emissions not arising from changes in carbon pools on the land base, (for example emissions from fossil fuel use and fertilization), are not accounted, as these emissions are expected to be similar to those that occurred within the project areaprior to the commencement of the project.

### Step 10: Market flexibility

Where the project causes a less than 3% change in the supply of a given product or service to any market, as determined in Step 5, market changes caused by the project may reasonably be assumed to be indistinguishable from normal market “noise”, and it is unlikely that any pricing change attributable to the project will incentivize a change in behavior on the part of suppliers to the market. However, project proponents must examine the market conditions to determine if flexibility mechanisms exist within the market which will mask or compensate for the effects of the project.

Such mechanisms may include:

* Surplus - The market for the good is typically in a surplus situation, with some wastage or low value use consuming the surplus.
* Substitution - Substitution of another existing good is likely to occur if any temporary shortfall occurs, and the substitute is in surplus.
* Under-utilized capacity - Existing lands suitable for production of the good without further clearance or other carbon impacts are under-utilized, and any shortfall could be made up from these lands.
* Intensification capacity - Intensification of production on existing lands producing the good represents the lowest cost path to replacement of the losses attributable to the project.

The best source for this data is likely to be local producers and intermediaries with a clear knowledge of the market dynamics and production limitations for the commodity or service.

If any of these mechanisms, or similar mechanisms which would tend to mask market signals, demonstrably exists, no leakage is assumed to occur for this product or service in this market. Otherwise, return to Step 6.

# 6 PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter**: | *Em* |
| Data unit: | tCO2e |
| Description: | Market leakage CO2 for year y |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The market leakage estimated for a given year |
| Any comment: |  |
| **Data Unit / Parameter:** | *Cc* |
| Data unit: | tCO2e |
| Description: | Carbon stocks of the identified land base under the management regime present in the baseline scenario |
| Source of data: | Calculated using appropriate modules |
| Justification of choice of data or description of measurement methods and procedures applied: | Tonnes of CO2e on the identified land based under the management regime that was present in the baseline scenario |
| Any comment: |  |
| **Data Unit / Parameter:** | *Cm* |
| Data unit: | tCO2e |
| Description: | Carbon stocks of the identified land base under the management regime expected to result from the market leakage in the project scenario |
| Source of data: | Calculated using appropriate modules |
| Justification of choice of data or description of measurement methods and procedures applied: | Carbon stocks of the identified land under the management regime expected to result from the  market leakage in the project scenario |
| Any comment: |  |

# 7 REFERENCES AND OTHER INFORMATION

None

## DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-16

METHODS FOR DEVELOPING A MONITORING PLAN

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 435](#_Toc12033)

[2 SUMMARY DESCRIPTION OF THE MODULE 435](#_Toc12034)

[3 DEFINITIONS 435](#_Toc12035)

[4 APPLICABILITY CONDITIONS 435](#_Toc12036)

[5 PROCEDURES 435](#_Toc12037)

[6 PARAMETERS 441](#_Toc12038)

[7 REFERENCES AND OTHER INFORMATION 441](#_Toc12039)

# SOURCES

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

# SUMMARY DESCRIPTION OF THE MODULE

This module sets out the methods and requirements for creating a monitoring plan for the project.

# DEFINITIONS

|  |  |
| --- | --- |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project. |
| **Carbon Stock:** | See VCS *Program Definitions.* |
| **Leakage:** | See VCS *Program Definitions.* |
| **Monitoring Plan:** | The plan in which a monitoring schedule and methods are documented. |
| **Project Area:** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Project Scenario:** | The actions and events which are expected to occur as a result of implementing the project. |

# APPLICABILITY CONDITIONS

None

# PROCEDURES

## Monitoring Plan

The monitoring plan must detail how the following will be monitored:

1. Project implementation.
2. Accounted pools and emissions, as chosen following module *TRS-3 Methods to Determine the Project Boundary.*
3. Natural disturbance.
4. Leakage.

These are expanded upon in the sections below. The project proponent must prepare a monitoring plan describing (for each separately) the following:

1. Purpose of the monitoring.
2. Technical description of the monitoring task.
3. Data to be collected.
4. Overview of data collection procedures.
5. Frequency of the monitoring.
6. Quality control and quality assurance procedure.
7. Data archiving.
8. Organization and responsibilities of the parties involved in all the above.

## Project Implementation

The rationale of monitoring project implementation is to document all project activities implemented by the project(including leakage prevention measures) that could cause an increase in GHG emissions compared to the baseline scenario.

The project proponent must perform the following:

1. Describe, date and geo-reference, as necessary, all measures implemented by the project.
2. Collect all relevant data to estimate carbon stock changes due to project activities and displacement of baseline activities, as well as GHG emissions due to leakage prevention measures. Refer to the relevant modules for the variables to be measured.
3. State whether the measures deviate from those described in the project description.
4. Record and justify any deviation to the interventions planned.

## Accounted Pools and Emissions

The monitoring plan must include the following:

1. A description of the estimation, modeling, measurement or calculation approaches to be used in monitoring the variable.
2. A description of how methods and procedures given in each relevant module will be used to estimate the values of monitored variables.
3. A description of how a requirement for re-stratification will be identified for all monitored variables, and how the re-stratification will be undertaken.
4. Where applicable, the standards to be used for derivation of data from remote sensing, if remote sensing is to be used. The standards given should be consistent with those used during the preparation of ex-ante projections.
5. Procedures to be followed in the case of an improvement of the quality of data and data analysis methods during the project crediting period.

## Natural Disturbance

Natural disturbances such as tsunami, sea level rise, volcanic eruption, landslide, flooding, permafrost melting, and pest and disease can impact the carbon stocks and non-CO2 GHG emissions of a project. Such changes can be abrupt or gradual and when significant, they must be factored out from the estimation of ex post net anthropogenic GHG emission reductions, as follows:

1. Where natural disturbances reduce the area within which the project activities are undertaken, or within which they have effect, measure the boundary of the polygons lost from the project area and exclude the area within such polygons from the project area in both the baseline and project scenarios.
2. Where natural disturbances have an impact on carbon stocks, measure the boundary of the polygons where such changes happened and the change in carbon stock within each polygon. Assume that a similar carbon stock change would have happened in the project area under the baseline scenario.

## Leakage

All sources of leakage identified as significant in the ex-ante assessment are subject to monitoring. The monitoring plan must detail the methods to be used to monitor leakage.

## Monitoring Frequency

The following table sets out the monitoring frequency of the data for each module used. The project proponent must ensure that data collection for each module used complies with monitoring frequencies set out below.

The methodology requires project proponents to monitor, recalculate and repeat measurements of certain components of the project through the (re)application of entire or part of modules as set out in Table 1 below, except where specific pools are not being accounted.

## Table 1: Monitoring frequency per module

|  |  |
| --- | --- |
| **Module name** | **Monitoring Frequency** |
| *TRS-3 Methods to Determine the Project Boundary* | Module can be applied at intervals of ≤ 5 years |
| *TRS-2 Methods to Project Future Conditions* | When baseline is required to be (re)assessed as per the latest version of the VCS rules |
| *TRS-1 Methods to Determine Stratification* | Module can be applied at intervals of ≤ 5 years |
| *VMD0021 Estimation of Stocks in the Soil Carbon Pool* | Data must be collected at intervals of ≤ 5 years |
| *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass* | Data must be collected at intervals of ≤ 5 years |
| *TRS-5 Estimation of Carbon Stocks in the Litter Pool* | Data must be collected at intervals of ≤ 5 years |
| *TRS-6 Estimation of Carbon Stocks in the Deadwood Pool* | Data must be collected at intervals of ≤ 5 years |
| *TRS-7 Estimation of Woody Biomass Harvesting and Utilization* | Data must be collected at intervals of ≤ 5 years |
| *TRS-8 Estimation of Carbon Stocks in the Long-* | Data must be collected at intervals of ≤ 5 years |
| *lived Wood Products Pool* |  |
| *TRS-9 Estimation of Domesticated Animal Populations* | Data must be collected every year |
| *TRS-10 Estimation of Emissions from Domesticated Animals* | Data must be collected at intervals of ≤ 5 years |
| *TRS-11 Estimation of Emissions of non CO2 GHGs from Soils* | Data must be collected at intervals of ≤ 5 years |
| *TRS-12 Estimation of Emissions from Power Equipment* | Data must be collected every year |
| *TRS-13 Estimation of Emissions from Biomass Burning* | Data must be collected after fire events |
| *TRS-14 Estimation of Emissions from Activity Shifting Leakage* | Data must be collected 1 year after the project start date and 5 years after the project start date |
| *TRS-15 Estimation of Emissions from Market Leakage* | Data must be collected at intervals of ≤ 5 years |
| *TRS-16 Methods for Developing a Monitoring Plan* | Not monitored. Projected at t =0 |
| *TRS-17 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities* | Recalculated before every verification event |

## Quality Assurance and Quality Control

Project proponents must undertake ongoing QA/QC during the preparation of the project description and other project documents, including monitoring reports, as follows:

1. Project proponents must document all steps undertaken during the use of this methodology, including the sources of data where data is not generated internally, and the methods used to generate data for data generated internally.
2. Project proponents must describe specific quality criteria for tasks or data types are given in the modules. Where such criteria are given project proponents must document the steps taken to meet these quality criteria.
3. Project proponents must undertake preparation and documentation of specific guidance on data collection techniques used, training of field crews in these techniques, and development of systematic procedures for checking on adherence to these standards.
4. For data derived from external sources, project proponents must include in their documentation any assessment of uncertainty attached to that data.
5. For data generated internally, project proponents must also generate uncertainty estimates for that data. During the preparation of project description and other documentation, project proponents will utilize and generate both qualitative and quantitative data. Depending on the type of data generated, uncertainty estimates must include one or both of the following elements:
   1. For all data types: A qualitative data assessment. A qualitative data assessment is an assessment of the factors which might influence the accuracy of the data. For example:
      1. Where the project proponent utilizes qualitative data on future management intentions of local farmers, gathered in interviews with farmers, the project proponent might assess factors such as:
         * The representativeness of the farmers interviewed, in relation to the total project area.
         * The conditions under which farmers were interviewed, including any possible biasing factors.
         * The range of conditions within which the answers are likely to remain valid.
      2. Where the project proponent gathers quantitative data on soil carbon, the project proponent must assess factors such as:
         * The range of past soil forming conditions within which the data gathering methods used would not be expected to produce accurate data (for instance, where soils consist of uneven layers of high and low carbon alluvial deposits, such that the specified sampling depth fails to capture a specific carbon rich layer where active change is expected to occur).
         * The possible influence of local scale change (change at a scale smaller than the scale of stratification) on soil carbon values, and possible sampling bias arising from these changes.
         * The possibility that a systematic sampling method has given rise to a sampling bias.
         * The possibility that the sampling equipment used introduced some contamination or bias.

For all data types, the qualitative assessment of possible error is of primary importance, and will form the context for the quantitative assessment of error.

* 1. For quantitative data types: A quantitative data assessment. Where quantitative data is gathered, the project proponent should utilize appropriate statistical methods to assess the degree of certainty of the data generated. Specific modules give methods and allowable ranges of uncertainty for specific data types.

Based on the above, project proponents must include as an appendix to the project description, and to each monitoring report, an assessment of the overall uncertainty of the estimation of current conditions, and where applicable the baseline or project projections. This assessment must include:

1. Documentation of the data gathering procedures used, and the results of the systematic checking procedures to ensure that these procedures were followed.
2. A qualitative summary of the possible sources of error or uncertainty with relation to the baseline and project projections, including:
   * The possible sources of methodological error in the collection of internally generated data, and the steps taken to ensure that such errors do not, have not or are not occurring.
   * The range of possible conditions, under which the estimations or projections are expected to remain accurate, and the types and estimated likelihood of conditions under which either estimations of current conditions or projections of future conditions might be significantly inaccurate.
   * Future conditions under which a re-assessment of the baseline condition must be considered, due to significant deviation from the expected conditions.

Where appropriate, and recognizing the qualitative assessment undertaken above, a quantitative assessment of the range of uncertainty associated with the assessment of current conditions, or the baseline or project projections must be undertaken. Care must be taken not to rely on such quantitative assessments where factors identified in the qualitative assessment may limit the reliability of statistical procedures.

# PARAMETERS

All parameters are set out in the respective modules.

# REFERENCES AND OTHER INFORMATION

None

**DOCUMENT HISTORY**

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

TRS-17

METHODS TO DETERMINE THE NET CHANGE IN ATMOSPHERIC GHG RESULTING FROM PROJECT ACTIVITIES

Version 1.0

16 November 2012 Sectoral Scope 14



Document Prepared by: The Earth Partners LLC.

**Table of Contents**

[1 SOURCES 2](#_Toc49981)

[2 SUMMARY DESCRIPTION OF THE MODULE 2](#_Toc49982)

[3 DEFINITIONS 2](#_Toc49983)

[4 APPLICABILITY CONDITIONS 2](#_Toc49984)

[5 PROCEDURES 2](#_Toc49985)

[6 PARAMETERS 8](#_Toc49986)

[7 REFERENCES AND OTHER INFORMATION 16](#_Toc49987)

# SOURCES

VCS module *VMD0017 Estimation of Uncertainty for REDD Project Activities (X-UNC)*

# SUMMARY DESCRIPTION OF THE MODULE

The module provides the methods required to sum up the estimated atmospheric GHG flux associated with the project area under either the baseline or project scenario for a given time period, and to estimate the uncertainty of project and baseline scenario carbon stock and emission calculations.

# DEFINITIONS

|  |  |
| --- | --- |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project. |
| **Livestock:** | Domesticated animals including dairy cattle, non-dairy cattle, buffalo, sheep, goats, camels, horses, mules, asses, swine, poultry, alpacas and llamas. |
| **Project Scenario:** | The actions and events which are expected to occur as a result of implementing the project. |

# APPLICABILITY CONDITIONS

None

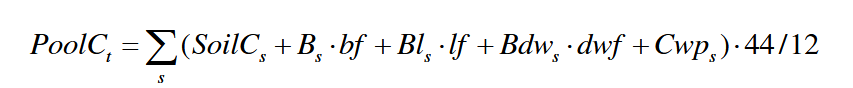
# PROCEDURES

**Introduction:**

Because GHG emissions are accounted as permanent, while GHG removals contained in pools have varying levels of impermanence risk, GHG pools and emissions are summarized separately in this module.

The uncertainty determination method may be used for project planning and must be used for GHG benefit determination. The method allows the project to determine whether the uncertainty of the atmospheric GHG benefit determination exceeds the appropriate level.

**Summation of GHG pools:**

** (19.1)

Where:

*PoolCt* = Total carbon in carbon pools at time t, tCO2e

|  |  |  |
| --- | --- | --- |
| *s* | = | Strata |
| *SoilCs* | = | The carbon content of the soil pool in stratum s at time t, tC |
| *Bs* | = | The living biomass content of stratum s at time t, t |
| *bf* | = | The conversion factor from living biomass to C = 0.5, tC/t |
| *Bls* | = | The litter biomass of stratum s at time t, t |
| *lf* | = | The conversion factor from litter biomass to C, tC/t |
| *Bdws* | = | The dead wood biomass of stratum s at time t, t |
| *dwf* | = | The conversion factor from deadwood biomass to C, tC/t |
| *Cwps* | = | The carbon content of long lived wood products resulting from the harvesting of wood in stratum s to time t, tC |
| *44/12* | *=* | Conversion factor from C to CO2, tCO2/tC |

Notes on variables:

**All variables:** Any carbon pools not accounted must be set to 0 in this equation.

|  |  |
| --- | --- |
| **SoilCs:** | Values are derived from estimations carried out using module *VMD0021*  *Estimation of Stocks in the Soil Carbon Pool*, or projections carried out using the *TRS-2 Methods to Project Future Conditions*, in the case of ex-ante projection of carbon pools. |
| **Bs**: | Values are derived from estimations carried out using the *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass*, or projections carried out using the *TRS-2 Methods to Project Future Conditions*, in the case of ex-ante projection of carbon pools. |
| **Bf:** | The default conversion factor is 0.5 for conversion from dry biomass to mass of carbon. |
| **Bls:** | Values are derived from estimations carried out using the *TRS-5 Estimation of Carbon Stocks in the Litter Pool*, or projections carried out using the  *TRS-2 Methods to Project Future Conditions*, in the case of ex-ante projection of carbon pools. |
| **Lf:** | Conversion factors from litter biomass to carbon must be determined using applicable literature, IPCC guidance, or testing of samples. |
| **Bdws**: | Values are derived from estimations carried out using *TRS-6 Estimation of*  *Carbon Stocks in the Dead Wood Pool*, or projections carried out using  *TRS-2 Methods to Project Future Conditions,* in the case of ex-ante projection of carbon pools. |
| **Dwf:** | Conversion factors from dead wood biomass to carbon must be determined using applicable literature, IPCC guidance, or testing of samples. |
| **Cwps:** | Values are derived from estimations carried out using the *TRS-8 Estimation* |

*of Carbon Stocks in the Long-lived Wood Products Pool*, or projections carried

out using the  *TRS-2 Methods to Project Future Conditions,* in the case of ex-

|  |  |  |
| --- | --- | --- |
| ante projection of carbon pools.    **Summation of GHG Emissions:** | |  |
|  | | (19.2) |
| Where: |  |
| *EmissionCt* | = Total emissions from time t=0 to time t, tCO2e |  |
| *z* | = The years from time t=0 to time t, yr |  |
| *El* | = Emissions from livestock management, tCO2e/yr |  |
| *Es* | = Emissions from soil resulting from management activities, tCO2e/yr | |
| *Eff* | = Emissions from burning of fossil fuels in power equipment during project management, tCO2e/yr | |
| *fe* | = Fire events within the selected time period | |
| *Eb* | = Emissions of non-CO2 gasses caused by fire events, tCO2e/fire event | |

Notes on variables:

* Any emissions not accounted must be set to 0 in this equation.
* Only emissions due to livestock management and fire events may be accounted under the baseline scenario*.*
* Emissions due to livestock management may only be accounted under the baseline scenario if those emissions are less than the livestock emissions under the project scenario.
* Emissions due to fire events may only be accounted under the baseline scenario if those emissions are less than the fire emissions under the project scenario.

**Summation of Leakage:**

## A black and white math equation AI-generated content may be incorrect. (19.3)

Where:

LeakageCt = Quantified leakage of the project over the baseline over the selected period, tCO2e

*Ed* = Emissions from displacement leakage over the selected period, tCO2e

*Em* = Emissions from market leakage over the selected period, tCO2e

**Summation of net change carbon stocks:**

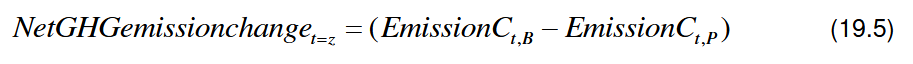
## A black text on a white background AI-generated content may be incorrect. (19.4)

Where:

*Netchangecarbonstockst=z =* Difference in carbon stocks in baseline and project scenario, tCO2e

*PoolCt,P* = Total carbon in carbon pools at time t=z under the project scenario, tCO2e

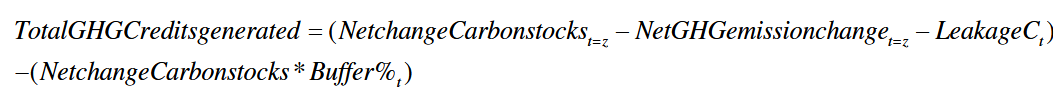
*PoolCt,B* = Total carbon in carbon pools at time t=z under the baseline scenario, tCO2e

**Summation of net change in GHG emissions:**

## (19.5)

|  |  |
| --- | --- |
| Where: |  |
| *NetGHGemissionchanget=z* = | Net change in GHG emissions for a period ending at time t=z due to the project activity, tCO2e |
| *EmissionCt,B* = | Total emissions from time t=0 to time t= z, under the baseline scenario, tCO2e |
| *EmissionCt,P* = | Total emissions from time t=0 to time t= z, under the project scenario, tCO2e |

**Summation of net change in atmospheric GHGs:**

The net changes in GHGs due to the project activities at time t=z will be:

|  |  |
| --- | --- |
| (19.6) | |
| Where: |  |
| *TotalGHGCreditsgenerated =* | GHG benefit of the project net of leakage and buffer. |
| *Netchangecarbonstockst=z =* | Difference in carbon stocks in baseline and project scenario, tCO2e |
| *NetGHGemissionchanget=z* = | Net change in GHG emissions at time t=z due to the project activity, tCO2e |
| LeakageCt = | Quantified leakage of the project over the baseline over the selected period, tCO2e |
| Buffer%t = | Percentage of required buffering as per latest *VCS AFOLU* |

*Non Permanence Tool* requirements

**Project uncertainty:**

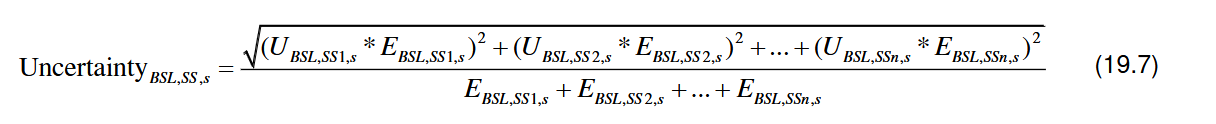
Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the measures/estimates of: area or other activity data, carbon stocks, biomass growth rates, expansion factors, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment, or estimates based on sound statistical sampling. Alternatively, indisputably conservative estimates of values can also be used, which will allow proponents not to calculate uncertainties for those variables, provided that the values used are based on verifiable literature sources or expert judgment. In this case the uncertainty is assumed to be zero for that variable.

Associated modules include methods for adjusting estimated values of carbon pools where uncertainties exceed specified limits. However, this module provides a procedure to combine uncertainty information and conservative estimates allowing the estimation of overall ex-post project uncertainty.

The uncertainty across the baseline and project emissions and carbon stocks is determined through the following three steps. In Steps 1 and 2 the uncertainty of the various carbon stocks, and emissions in both the baseline (step 1) as well as the project scenario (step 2) will be determined. In Step 3 both uncertainties are summarized in one project uncertainty.

**Step 1a: Estimation of the baseline uncertainty within the strata**

Uncertainty must be expressed as the 95% confidence interval as a percentage of the mean.

 Where:

UncertaintyBSL,SS,s  Percentage uncertainty in the combined carbon stocks and greenhouse gas emissions in the baseline scenario in stratum s, %

UBLS,SS,s Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline scenario in stratum s (1,2,….s represents different carbon pool and/or GHG source,%

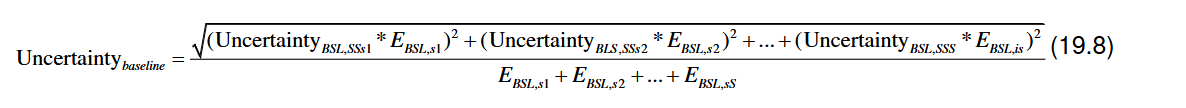
EBLS,SS,s Carbon stock or GHG sources (e.g. trees, down dead wood, soil organic

carbon, emission from fertilizer addition, emission from biomass burning etc.) in stratum s (1,2,…s represent different carbon pools and/or GHG sources) in the baseline case; tCO2e

i 1,2,3,… s strata

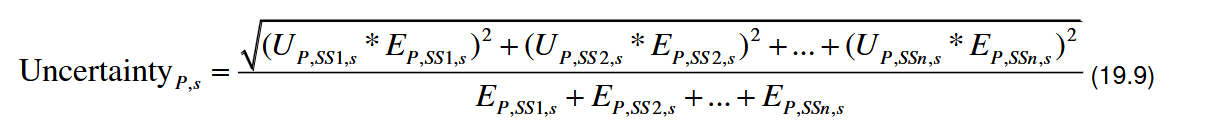
In equation 19.7 the errors in each pool and emission are weighted according to the size of the pool or emission.

**Step 1b: Total uncertainty of the baseline scenario is the square root of the sum of the squares of all the stratum uncertainties on a weighted basis.**



|  |  |
| --- | --- |
| Where: |  |
| UncertaintyBaseline | Total uncertainty in the combined carbon stocks and greenhouse gas sources in the baseline scenario, % |
| UncertaintyBSL,SS,s | Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in stratum s in the baseline scenario, % |
| EBLS,SS,s | Carbon stock or GHG sources (e.g. trees, down dead wood, soil organic carbon, emission from fertilizer addition, emission from biomass burning etc.) in stratum s (1,2,…s represent different carbon pools and/or GHG sources) in the baseline scenario; tCO2e |
| i | 1,2,3,… s strata |

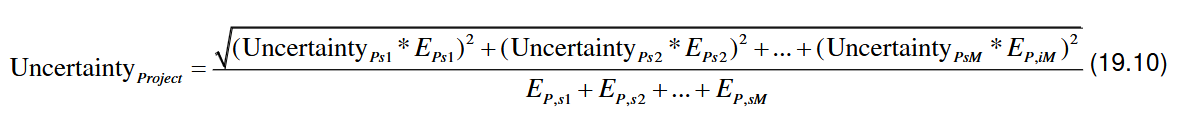
**Step 2a: Estimation of the project scenario uncertainty within the strata**



Where

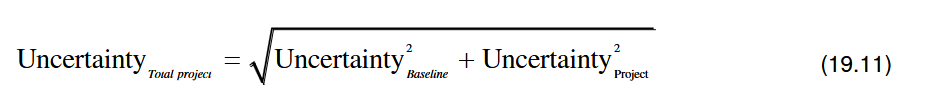
|  |  |
| --- | --- |
| UncertaintyP.s = | Uncertainty in the combines carbon stocks and greenhouse gas sources in the project scenario in stratum,% |
| Up,SS,s= | Percentage uncertainty (expressed as 95% confidence interval as the percentage of the mean where appropriate) for the carbon stocks, Greenhouse gas emissions and leakage emissions in the project scenario in stratum s (1,2…s represents different carbon pools and/or  GHG sources in the with-project case; tCO2e) |
| EP,SS,s= | Carbon stocks or GHG emission (Living biomass, Dead wood, Litter Soil carbon etc.) in stratum I (1,2…s represents different carbon pools and/or GHG sources) in the with-project case; tCO2e |
| s= | 1,2,3.. s strata |

**Step 2b: Total uncertainty of the project line scenario is the square root of the sum of the squares of all the stratum uncertainties on a weighted basis**



|  |  |
| --- | --- |
| Where: |  |
| Uncertainty Project = | Total uncertainty in project scenario, % |
| Uncertainty P,s = | Uncertainty in the combines carbon stocks and greenhouse gas sources in the project scenario in stratum,% |
| EP,sM= | Sum of combined carbon stocks and GHG sources (e.g. living biomass, dead wood, soil carbon, emissions from livestock and leakage in stratum s (1,2,3, …s) |
| i,= | 1,2,3, s strata |

***Step 3: Total project uncertainty:***



|  |  |
| --- | --- |
| Where: |  |
| Uncertainty Total project | = total uncertainty of the projects atmospheric GHG benefit, % |
| Uncertainty Baseline quantification, % | = total uncertainty of the baseline scenario emissions and carbon stock |
| Uncertainty Project quantification, % | = total uncertainty of the project scenario emissions and carbon stock |

# PARAMETERS

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Bdws* |
| Data unit: | T |
| Description: | Deadwood biomass |
| Source of data: | *TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool* |
| Justification of choice of data or description of measurement methods and procedures applied: | The dead wood biomass of stratum s at time t |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *bf* |
| Data unit: | tC/t |
| Description: | Carbon content of living biomass |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | the conversion factor from living biomass to C =  0.5 |
| Any comment: |  |
| **Data Unit / Parameter:** | *Bls* |
| Data unit: | T |
| Description: | *TRS-5 Estimation of Carbon Stocks in the Litter Pool* |
| Source of data: | Module : Litter |
| Justification of choice of data or description of measurement methods and procedures applied: | the litter biomass of stratum s at time t |
| Any comment: |  |
| **Data Unit / Parameter:** | *Bs* |
| Data unit: | T |
| Description: | Living biomass |
| Source of data: | *TRS-4 Estimation of Carbon Stocks in Living Plant Biomass* |
| Justification of choice of data or description of measurement methods and procedures applied: | The living biomass content of stratum s at time t |
| Any comment: |  |
| **Data Unit / Parameter:** | *Cwps* |
| Data unit: | tC |
| Description: | Carbon in long lived wood products |
| Source of data: | *TRS-8 Estimation of Carbon Stocks in the Long-lived Wood Products Pool* |
| Justification of choice of data or description of measurement methods and procedures applied: | The carbon content of long lived wood products resulting from the harvesting of wood in stratum s to time t |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *dwf* |
| Data unit: | tC/t |
| Description: | Carbon content of deadwood |
| Source of data: | *TRS-6 Estimation of Carbon Stocks in the Dead Wood Pool* |
| Justification of choice of data or description of measurement methods and procedures applied: | The conversion factor from deadwood biomass to C |
| Any comment: |  |
| **Data Unit / Parameter:** | *Eb* |
| Data unit: | tCO2e/yr |
| Description: | Fire event emissions |
| Source of data: | *TRS-13 Estimation of Emissions from Biomass Burning* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions of non-CO2 gasses caused by fire events |
| Any comment: |  |
| **Data Unit / Parameter:** | *Ed* |
| Data unit: | tCO2e/yr |
| Description: | Displacement leakage |
| Source of data: | *TRS-14 Estimation of Emissions from Activity Shifting Leakage* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from displacement leakage over the selected period |
| Any comment: |  |
| **Data Unit / Parameter:** | *Eff* |
| Data unit: | tCO2e/yr |
| Description: | Fossil fuel emissions |
| Source of data: | *TRS-12 Estimation of Emissions from Power Equipment* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from burning of fossil fuels in power equipment during project management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *El* |
| Data unit: | tCO2e/yr |
| Description: | Livestock emissions |
| Source of data: | *TRS-10 Estimation of Emissions from Domesticated Animals* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from livestock management |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Em* |
| Data unit: | tCO2e |
| Description: | Market leakage |
| Source of data: | *TRS-15 Estimation of Emissions from Market Leakage* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from market leakage over the selected period |
| Any comment: |  |
| **Data Unit / Parameter:** | *EmissionCt,B* |
| Data unit: | tCO2e |
| Description: | Baseline emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total emissions from time t=0 to time t= z, under the baseline scenario |
| Any comment: |  |
| **Data Unit / Parameter:** | *EmissionCt,P* |
| Data unit: | tCO2e |
| Description: | Project emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total emissions from time t=0 to time t= z, under the project scenario |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *Es* |
| Data unit: | tCO2e/yr |
| Description: | Soil emissions |
| Source of data: | *VMD0021 Estimation of Stocks in the Soil Carbon Pool* |
| Justification of choice of data or description of measurement methods and procedures applied: | Emissions from soil resulting from management activities |
| Any comment: |  |
| **Data Unit / Parameter:** | *fe* |
| Data unit: | # |
| Description: | Fire events |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Fire events within the selected time period |
| Any comment: |  |
| **Data Unit / Parameter:** | *lf* |
| Data unit: | tC/t |
| Description: | Carbon content of litter |
| Source of data: | Module : Litter |
| Justification of choice of data or description of measurement methods and procedures applied: | The conversion factor from litter biomass to C |
| Any comment: |  |
| **Data Unit / Parameter:** | *NetGHGt=z* |
| Data unit: | tCO2e |
| Description: | Net GHG effects of the project |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Net change in atmospheric GHGs at time t=z due to the project activity |
| Any comment: |  |

|  |  |
| --- | --- |
| **Data Unit / Parameter:** | *PoolCt* |
| Data unit: | tCO2e |
| Description: | Total carbon in pools |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total carbon in carbon pools at time t, |
| Any comment: |  |
| **Data Unit / Parameter:** | *PoolCt,B* |
| Data unit: | tCO2e |
| Description: | Baseline pools |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total carbon in carbon pools at time t=z under the baseline scenario, |
| Any comment: |  |
| **Data Unit / Parameter:** | *PoolCt,P* |
| Data unit: | tCO2e |
| Description: | Baseline pools |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total carbon in carbon pools at time t=z under the project scenario, |
| Any comment: |  |
| **Data Unit / Parameter:** | *SoilCs* |
| Data unit: | tC |
| Description: | Soil pool carbon |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The carbon content of the soil pool in stratum s at time t |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *s* |
| Data unit: |  |
| Description: | Strata |
| Source of data: | Module : Stratification |
| Justification of choice of data or description of measurement methods and procedures applied: | Strata |
| Any comment: |  |
| Data Unit / Parameter: | z |
| Data unit: | yr |
| Description: | Years in the selected period |
| Source of data: | *TRS-16 Methods for Developing a Monitoring Plan* |
| Justification of choice of data or description of measurement methods and procedures applied: | The years from time t=0 to time t |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *LeakageCt* |
| Data unit: | Tonnes |
| Description: | Market leakage and activity shifting leakage |
| Source of data: | *TRS-14 Estimation of Emissions from Activity*  *Shifting Leakage*  *TRS-15 Estimation of Emissions from Market Leakage* |
| Justification of choice of data or description of measurement methods and procedures applied: | The years from time t=0 to time t |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *UncertaintyBSL,SS,s* |
| Data unit: | % |
| Description: | Percentage uncertainty in the combined carbon stocks and greenhouse gas emissions in the baseline scenario in stratum s, |
| Source of data: | calculated |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *UBLS,SS,s* |
| Data unit: | % |
| Description: | Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline scenario in stratum s (1,2,….s represents different carbon pool and/or GHG source |
| Source of data: | Calculated through data collected from appropriate modules |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *EBLS,SS,s* |
| Data unit: | tCO2e |
| Description: | Carbon stock or GHG sources (e.g. trees, down dead wood, soil organic carbon, emission from fertilizer addition, emission from biomass burning etc.) in stratum s (1,2,…s represent different carbon pools and/or GHG sources) in the baseline case; |
| Source of data: | Modules determining various variables |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *s* |
| Data unit: | Dimensionless |
| Description: | 1,2,3,… s strata |
| Source of data: |  |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Up,SS,s* |
| Data unit: | % |
| Description: | Carbon stocks or GHG emission (Living biomass,  Dead wood, Litter Soil carbon etc.) in stratum I  (1,2…s represents different carbon pools and/or  GHG sources) in the project scenario. |
| Source of data: | Modules determining various variables |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *Ep,SS,s* |
| Data unit: | tCO2e |
| Description: | Carbon stocks or GHG emission (Living biomass,  Dead wood, Litter Soil carbon etc.) in stratum I  (1,2…s represents different carbon pools and/or  GHG sources) in the project scenario |
| Source of data: | Modules determining various variables |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

|  |  |
| --- | --- |
| Data Unit / Parameter: | *UncertaintyProject* |
| Data unit: | % |
| Description: | Total uncertainty in project scenario |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: |  |
| Any comment: |  |

# REFERENCES AND OTHER INFORMATION

None

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

# Appendix 5.0 Verra VM0021



Approved VCS Methodology

VM0021

Version

1

.0

, 16 November 2012

Sectoral Scope 14

Soil Carbon Quantification

Methodology

©201

2

The Earth Partners LLC.

Methodology developed by:



The Earth Partners LLC.

### RELATIONSHIP TO APPROVED OR PENDING METHODOLOGIES

To date no similar methodologies have been approved under the VCS Program.

Four related methodologies are currently under development or approved under the VCS Program:

* *ALM Adoption of Sustainable Grassland Management through Adjustment of Fire and Grazing* (methodology under development)- This methodology is limited to activities on uncultivated grasslands where fire is a potential occurrence.
* *Agricultural Land Management – Improved Grassland Management* (methodology under development) – This methodology is dependent on the existence of applicable, tested soil models for determining soil carbon.
* *VM0017 Adoption of Sustainable Agricultural Land Management (SALM)* – This methodology focuses on a specific set of management practices
* *Methodology for Sustainable Grassland Management (SGM)* (methodology under development) *–* This methodology is specific to sustainable grassland management projects where ongoing degradation is occurring and is expected to continue
* *Calculating Emission Reductions in Rice Management Systems* (methodology under development) *–* This methodology is specific to reducing emissions from rice cultivation.

All of these existing proposed methodologies focus on specific elements of the ALM continuum. The use of soil carbon prediction models such as Century and DNDC are widely applied in these methodologies. This methodology is much more general, and is designed to be applicable to projects where a wide variety of activities may occur under the baseline or project scenario, such as timber harvesting, and fertilization. Soil carbon is measured in both the baseline and project scenarios and the DNDC model is used only for quantifying the methane and nitrous oxide emissions.

### Table of Contents

[1 Sources 4](#_Toc45945)

[2 Summary Description of the Methodology 4](#_Toc45946)

[3 Definitions 7](#_Toc45947)

[4 Applicability Conditions 8](#_Toc45948)

[4.1 Mandatory Conditions 8](#_Toc45949)

[4.2 Optional Conditions 9](#_Toc45950)

[5 Project Boundary 10](#_Toc45951)

[6 Procedure for Determining the Baseline Scenario 10](#_Toc45952)

[7 Procedure for Demonstrating Additionality 11](#_Toc45953)

[8 Quantification of GHG Emission Reductions and Removals 11](#_Toc45954)

[8.1 Baseline Emissions 11](#_Toc45955)

[8.2 Project Emissions 17](#_Toc45956)

[8.3 Leakage 25](#_Toc45957)

[8.4 Summary of GHG Emission Reduction and/or Removals 27](#_Toc45958)

[9 Monitoring 28](#_Toc45959)

[9.1 Data and Parameters Available at Validation 28](#_Toc45960)

[9.2 Data and Parameters Monitored 28](#_Toc45961)

[9.3 Description of the Monitoring Plan 28](#_Toc45962)

[10 References and Other Information 28](#_Toc45963)

# SOURCES

This methodology and its modules have been developed on the accounting principles as set out in: IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry.

The modules used in this methodology are:

* *VMD0018 Methods to Determine Stratification*
* *VMD0019 Methods to Project Future Conditions*
* *VMD0020 Methods to Determine the Project Boundary*
* *VMD0021 Estimation of Stocks in the Soil Carbon Pool*
* *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*
* *VMD0023 Estimation of Carbon Stocks in the Litter Pool*
* *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*
* *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*
* *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*
* *VMD0027 Estimation of Domesticated Animal Populations*
* *VMD0028 Estimation of Emissions from Domesticated Animals*
* *VMD0029 Estimation of Emissions of Non-CO2 GHG from Soils*
* *VMD0030 Estimation of Emissions from Power Equipment*
* *VMD0031 Estimation of Emissions from Biomass Burning*
* *VMD0032 Estimation of Emissions from Activity Shifting Leakage*
* *VMD0033 Estimation of Emissions from Market Leakage*
* *VMD0034 Methods for Developing a Monitoring Plan*
* *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project*

*Activities*

# SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology describes methods for quantifying and monitoring changes in carbon accrual in, and emissions from, soils, as well as from other GHG pools and sources which may be impacted by soil focused activities. The methodology is designed based on guidance provided in the IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry. This methodology has been designed to be applicable to conservation, ecosystem restoration and agricultural projects, as well as other projects where the management of soils directly, or management of hydrology, fertility and vegetation systems, can affect changes in soils and soil carbon. The methodology is applicable to a range of project activities designed to improve soils, including changes to agricultural practices, grassland and rangeland restorations, soil carbon protection and accrual benefits from reductions in erosion, grassland protection projects, and treatments designed to improve diversity and productivity of grassland and savanna plant communities.

The intention of the developers has been to create a methodology which includes sufficient detail on methods to allow a wide range of project proponents to use the methods during the development of soil carbon projects. However, accurately estimating and projecting the values of the various ecosystem carbon pools does require a significantlevel of technical ability on the part of the project proponent team. It is therefore expected that in many cases landowners and farmers may need to work with people with specific technical skills to complete the development of a soil carbon project description (PD) using this methodology.

This methodology provides methods for the quantification of soil carbon, as well as methods for quantifying changes in vegetation and litter pools which can be impacted by project activities, as compared with the baseline scenario.

This methodology does not address projects designed to enhance carbon sequestration in ancient soils (paleosols) that have been buried by more recent soil formations. While the same methods presented here are applicable to characterize the buried substrates, other methods (such as drilling rigs with a deeper boring capacity and split spoon sampling equipment) are beyond the scope of this methodology, which is focused on the extant active soil surfaces and active present day rooting zones soils.

This methodology is focused on addressing the following key variables:

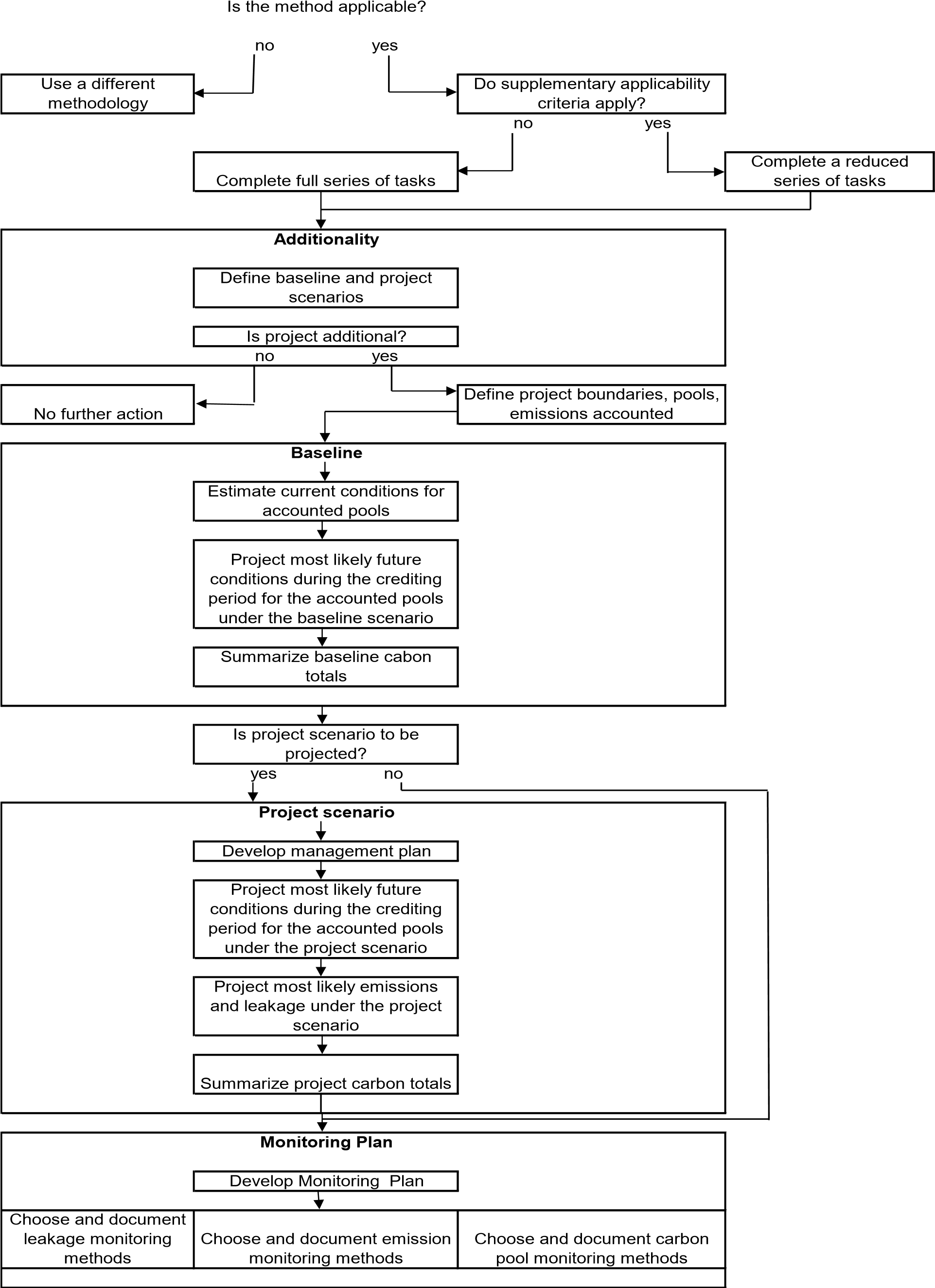
* Estimating the amount of carbon in the soil, litter, and living vegetation pools at the start of the project;
* Monitoring and documenting changes in soil carbon and the other carbon pools over time under the project scenario;
* Projecting changes in soil carbon and other pools under the baseline scenario;
* Estimating emissions of nitrous oxides and methane from soils, and,
* Estimating project leakage.

The methodology has been designed using a modular approach. This methodology document lays out the steps required to fulfill estimation, projection and quantification requirements for projects wishing to register credits under the VCS. The methodology calls on the associated modules for specific techniques and options for estimating or projecting the GHG impacts of changes in specific pools and emissions.

The methodology requires the completion of four main tasks, each of which is comprised of a number of sub-tasks:

1. Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario
2. Task 2: Ex-ante estimation and projection of carbon pools and emissions under the baseline scenario
3. Task 3: Ex-ante estimation and projection of carbon pools and emissions under the project scenario
4. Task 4: Development of a monitoring plan subsequent ex-post monitoring of pools and emissions under the project scenario as well as under the baseline scenario if a monitored baseline is used, and monitoring of leakage.

The overall process used by the methodology is shown in the following methodology map.



# DEFINITIONS

|  |  |
| --- | --- |
| **Activity Shifting Leakage:** | Activities that are moved by local actors from within the project area to outside due to the project, and which result in losses of carbon in pools outside the project area. |
| **Agent:** | A person or organization undertaking actions which impact the management of carbon pools and emissions. |
| **Baseline:** | The total amount of carbon within the project area in absence of the project. |
| **Baseline Scenario:** | The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project. |
| **Carbon Project:** | See *VCS Program Definitions* for project. |
| **Conservative:** | Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables. |
| **Coarse Fragments:** | Pieces of rock or cemented soils > 2mm in diameter, and therefore too large to pass through the screen used in the laboratory prior to laboratory analyses. |
| **Directly Attributable:** | The change or effect occurs as result of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be primarily and directly caused by the previous event in the chain. Analysis of the linkages in the chain should show that for each one, the previous event is at least 75% responsible for the next event. For this reason, the relationship between an event, or the actions of an agent, and the directly attributable effect, typically consist of not more than a few causal linkages. |
| **Ex-ante:** | Before the fact. Projection of values or conditions in the future. |
| **Ex-post:** | After the fact. Estimation of values or conditions in the present or past. |
| **Long Lived Wood Products:** | Products produced from harvested timber which is expected to persist and to sequester carbon for an extended period of time – typically 100 years, unless there is a specific reason for using a different time period. |
| **Monitoring Event:** | The time at which monitoring of all of the relevant variables is undertaken, to determine the net change in atmospheric carbon attributable to the project. |
| **Monitoring Period:** | The time period specified in a monitoring report during which GHG |

emission reduction or removals were generated by the project.

|  |  |
| --- | --- |
| **Monitoring Plan:** | Plan in which a monitoring schedule and methods will be documented. |
| **Planned:** | Changes in the value of the variable are under the control of identified agents who are independent of the project proponent. |
| **Project Area :** | The area or areas of land on which the project proponent will undertake the project activities. |
| **Project Crediting Period:** | See *VCS Program Definitions.* |
| **Project Scenario:** | The actions and events which are expected to occur as a result of implementing the project. |
| **Significant:** | A pool or source is significant if it does not meet the criteria for being deemed de minimis. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. |
| **Stratification:** | The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the  stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people. |
| **Stratum (plural strata):** | An area of land within which the value of a variable, and the processes leading to change in that variable, are relatively homogenous. |
| **Verification Date:** | A date, at which an independent verifier audits the results of monitoring. |
| **Woody Biomass:** | Biomass which exists primarily in the form of lignified tissues, such as that of shrubs and trees. Typically accounting of woody biomass includes the non woody parts (leaves, etc.) of plants which contain woody biomass. |

# APPLICABILITY CONDITIONS

## Mandatory Conditions

All projects using this methodology must meet the following conditions:

1. Projects must meet the most recent VCS requirements for one of the following three Agricultural Land Management activities:
   * Improved Cropland Management (ICM)
   * Improved Grassland Management (IGM)
   * Cropland and Grassland Land-use Conversions (CGLC)
2. As of the project start date all of the project areaconsists of grasslands or croplands. Crops may include woody species grown for food products, fuel products or timber, providing that the densities of these crops do not meet the requirements for definition of these lands as forest lands. The project area must not consist of forest, wetlands, or peatlands, as such terms are defined under the VCS.
3. The onlybaseline activities that could be displaced by the project activities are grazing and fodder production, crop production and timber production.
4. Project activities must not include changes in surface and shallow (<1m) soil water regimes through flood irrigation, drainage or other significant anthropogenic changes in the ground water table.
5. The project activity must not cause a significant change in termite populations, as compared with the baseline scenario.

## Optional Conditions

The following conditions do not need to be met to utilize the methodology. However, each of these conditions allows the simplification of the methodology through the elimination of the requirement for the completion of specific tasks.

1. The activities and agents which have caused the degradation of the croplands, grasslands or rangelands are expected to continue to impact the area in the absence of the project activity. On that basis, it can be demonstrated that the total carbon content of the soil organic and inorganic carbon pools within the project area is highly unlikely to increase under the baseline scenario during the project crediting period.

Consequence if met: Project proponent may conservatively assume that soil carbon content for all future dates under the baseline scenario shall be accounted as equal to the current soil carbon content, subject to re-assessment at year 10, as required under the VCS rules.

1. Changes in above and below ground living biomass pools within the project area can be shown to be insignificant under either the baseline or project scenarios.

Consequence if met: Project proponent is not required to complete Tasks 2.4, 2.5, 2.6, 3.3, 3.4, 4.3 and 4.4 of this document.

1. Woody biomass is found within the project area, but amounts of current and projected wood harvest under the baseline and project scenarios are not significant.

Consequence if met: Project proponent is not required to complete Tasks 2.7, 2.8, 2.9, 3.5, 3.6, 4.5, and 4.6 of this document.

1. GHG emissions from populations of domesticated animals are expected to remain the same or decline under the project scenario as compared with the baseline scenario.

Consequence if met: Project proponent is not required to complete Tasks 2.12, 2.13, 2.14, 3.8, 3.9, 4.8, and 4.9 of this document.

1. No significant change is expected to occur in the amounts or locations of any of the following conditions or activities between the baseline scenario and the project scenario:
   * Amount or location of application of organic or inorganic fertilizers.
   * Amount or location of domesticated animal grazing and deposition of manure or urine.
   * Amount or location of areas subject to flooding, and duration of flooding.
   * Amount or location of nitrogen fixing species.

Consequence if met: Project proponent is not required to complete Tasks 2.15, 2.16, 3.10, and 4.12 of this document.

# PROJECT BOUNDARY

#### Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario

***Task 1.1 Project boundary determination***

**Requirement:** For all projects

**Goal:** To determine the project boundary for baseline scenario and additionality purposes.

**Method:** Determine the project boundary using the module *VMD0020 Methods to Determine Project Boundary*

# PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

#### Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario (continued)

***Task 1.2 Baseline scenario determination***

**Requirement:**Required for all projects.

**Goal:** To determine the most plausible baseline scenario.

**Method:** Determine the baseline scenario(s) for the project area using the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities.*

The tool has been designed for A/R CDM project activities, but is used for the purposes of this methodology in an ALM context. As such, the following applies:

* Where the tool refers to A/R it must be understood as referring to ALM activities.
* Where the tool refers to forestation, it must be understood as referring to the project agricultural land management activities, and where the tool refers to forest, it must be understood as referring to agricultural land.
* Where the tool refers to CDM, it must be understood as referring to VCS.
* Where the tool refers to tCERs or lCERs, it must be understood as referring to VCUs.
* In case there is a conflict between the CDM tool requirements and the VCS rules, then the VCS rules must be followed.
* Where the tool makes reference to events occurring before or after December 31 1989, it must be understood as referring to events occurring before or after 10 years prior to the project start date.

Use of the tool is subject to the following:

* Applicability conditions: The tool is applicable for all VCS ALM project types that comply with the VCS eligibility rules as set out by AFOLU Requirements v3.2 section 4.2.2, or updated version
* Step 0: Start Date: Must follow most up to date VCS rules.
* Step 1 Point 9: Identify the alternative land management scenario in absence of the VCS ALM project

# PROCEDURE FOR DEMONSTRATING ADDITIONALITY

#### Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario (continued)

***Task 1.3 Demonstration of additionality***

**Requirement:** Required for all projects

**Goal:** to determine the additionality of the project.

**Method:** The project proponent must demonstrate whether or not the proposed project activity is additional using the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities*, following the same guidance given in section 6 above, or use the latest version of the VCS *Tool for Demonstration and Assessment of Additionality in VCS AFOLU Project Activities*.

# QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

## Baseline Emissions

Estimation of the carbon content of current pools, and projection of carbon pools and emissions under the baseline scenario is undertaken using the following the steps:

##### Task 2: Ex-ante estimation and projection of carbon pools and emissions under the baseline scenario

***Task 2.1 Project area stratification for soil carbon***

**Requirement**: Required for all projects.

**Goal**: To divide the project areainto one or more strata within which the existing soil carbon pools and soil carbon dynamics are relatively uniform.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

***Task 2.2 Estimation of the current carbon content of the soil carbon pool per unit of area, for each stratum***

**Requirement**: Required for all projects.

**Goal**: To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to estimate, at the required levels of statistical precision and accuracy, the amount of soil carbon per unit area.

**Methods**: Use module *VMD0022 Estimation of Stocks in the Soil Carbon Pool*.

***Task 2.3 Projection of the future carbon content of the soil carbon pool per unit of area, for each stratum***

**Requirement**: Required for all projects.

**Goal**: To project the future organic and inorganic soil carbon content per unit area in each stratum for each projected verification date within the project crediting period under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, and *VMD0021 Estimation of Stocks in the Soil Carbon Pool*, unless optional applicability condition (a) (See Section 4) is met.

**Task Notes**: If optional applicability condition (a) of this methodology is met, soils within the project area are demonstrated to be subject to continued degradation. Therefore, gains in soil carbon under the baseline scenario do not need to be projected. If this applicability condition is met, the methodology allows the project proponent to conservatively assume that the current carbon content of the soils will continue to be the carbon content of the soils throughout the project crediting period under the baseline scenario. In this case, no further work need be done on this task. This approach follows the simplifying precedent set in *CDM AR-AM0001*, now part of the consolidated methodology *CDM AR-ACM0002*.

***Task 2.4 Project area stratification for biomass***

**Requirement**: Required for all projects where the difference in total above and below ground biomass carbon between the project scenario and the baseline scenario at any time after the project start date is expected to be significant. Optional for all other projects.

**Goal**: To divide the project area into one or more strata within which the existing vegetation carbon pools and vegetation dynamics are relatively uniform.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with above and below ground biomass stocks per unit area as the relevant variable *X*.

***Task 2.5 Estimation of the carbon content of current aboveground woody and non-woody biomass and below ground living biomass pools***

**Requirement**: Same criteria as Task 2.4.

**Goal**: To sample the aboveground biomass pools and derive the belowground biomass pool in each stratum with a sampling intensity sufficient to estimate, at the required levels of statistical precision and accuracy, the amount of biomass carbon per unit area.

**Methods**: Use module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*.

***Task 2.6 Projection of future biomass pools under the baseline scenario***

**Requirement**: Same criteria as Task 2.4.

**Goal**: To determine the most likely future changes in total biomass within the project area under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with biomass pools as the relevant variable *X*.

***Task 2.7 Estimation of the amount of current wood harvest from within the project area used for production of long lived wood products***

**Requirement**: Required where the harvest of significant amounts of woody biomass currently occurs within the project area, or is expected to occur in the future under the baseline scenario, and some or all of that woody biomass is used for the production of long lived wood products. Optional and not recommended in all other cases.

**Goal**: To estimate the current amount of woody biomass harvesting taking place within the project area.

**Methods**: Use module *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*.

***Task 2.8 Projection of future wood harvest outputs***

**Requirement**: Same criteria as Task 2.7.

**Goal**: To project the most probable amount of woody biomass harvesting, and utilization of that harvest for the production of long lived wood products, that is expected to occur under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with wood harvest and utilization for long lived wood products as the relevant variable *X*.

***Task 2.9 Long Lived Wood Products***

**Requirement**: Same criteria as Task 2.7.

**Goal**: To project the amount of carbon which will be sequestered in long lived wood products under the baseline scenario.

**Methods**: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Tasks 2.7 and 2.8 as the inputs.

***Task 2.10 Estimation of current dead wood pools within the project area***

**Requirement**: Required where there are significant amounts of dead wood in the project area at the project start date, and removals of dead wood through utilization, reduced inputs or accelerated burning as part of a management activity are expected to occur under the project scenario. Optional under all other circumstances.

**Goal**: To estimate the current amount of biomass contained in dead wood pools.

**Methods**: Use module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*.

***Task 2.11*** ***Projection of future dead wood pools within the project area***

**Requirement**: Same as Task 2.10.

**Goal**: To project the amount of biomass which will be contained in dead wood pools under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with dead wood pools as the relevant variable *X*.

***Task 2.12 Estimation of current average domesticated animal populations within the project area***

**Requirement**: Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances **Goal**: To estimate the average current populations of domesticated animals within the project area.

**Methods**: Use the module *VMD0027 Estimation of Emissions from Domesticated Animals*.

***Task 2.13 Projection of future domesticated animal populations under the baseline scenario***

**Requirement**: Same as Task 2.12.

**Goal**: To project the future populations of domesticated animals under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with domesticated animal populations as the relevant variable *X.*

**Task Notes:** If at any time within the project crediting period the populations of domesticated animals under the baseline scenario are projected to be greater than those found at the project start date, populations at that time must be accounted as being equal to current levels. Conservatively, this methodology does not account for projected increases in animal populations and resulting emissions under the baseline scenario.

***Task 2.14 Estimation of emissions of GHGs from domesticated animals within the project area under the baseline scenario***

**Requirement**: Same as Task 2.11.

**Goal**: To estimate GHG emissions from current and projected future domesticated animal populations under the baseline scenario.

**Methods**: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*, with the outputs from Tasks 2.9 and 2.10 as the inputs.

***Task 2.15 Estimation of current soil emissions of N2O or CH4 from within the project area***

**Requirement**: Required where emissions of N2O or CH4 from the soils within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances.

**Goal**: To estimate the current emissions of N2O or CH4 from within the project area.

**Methods**: Use module *VMD0029 Emissions of Non-CO2 GHGs from Soils*.

***Task 2.16 Projection of future emissions of N2O or CH4 from the soils within the project area***

**Requirement**: Required if at any time within the project crediting period the emissions of N2O or CH4 from the soils within the project area under the baseline scenario are projected to be greater than those found under the project scenario. Optional under all other circumstances.

**Goal**: To project future emissions from soils under the baseline scenario, in the case that these emissions are expected to decline.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils*, as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0029 Estimation of Emissions of Non-CO2 GHG from Soils* to estimate the projected future emissions.

***Task 2.17 Projected emissions from use of power equipment***

**Requirement**: Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

**Goal**: To project GHG emissions for the monitoring period from the use of power equipment under the baseline scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to activities within the project area are all accounted as baseline or project emissions, whether or not the actual emissions occur within the project area.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with fuel uses in power equipment as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0030 Estimation of Emissions from Power Equipment* to estimate the projected future emissions.

***Task 2.18 Estimation of current litter pools.***

**Requirement**: Required where significant decreases in litter pools within the project area are expected under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances.

**Goal**: To estimate the carbon content of the litter pool within the project area.

**Methods**: Use module *VMD0023 Estimation of Carbon Stocks in the Litter Pool.*

***Task 2.19 Projection of future litter pools***

**Requirement**: Same as Task 2.18.

**Goal**: To project emissions from future litter pools under the baseline scenario where these emissions are expected to decline under the baseline scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0023 Estimation of Carbon Stocks in the Litter Pool*, as the relevant variable(s) *X.*

**Task Notes:** If at any time in theproject crediting period the litter pools within the project areaunder the baseline scenario are projected to be less than those at the project start date, litter pools for that time period must be accounted as being equal to levels at the project start date. Conservatively, this methodology does not account for projected decreases in litter pools under the baseline scenario.

***Task 2.20 Summation of estimates and projections under the baseline scenario***

**Requirement**: Required for all projects.

**Goal**: To sum current and future carbon sequestration and emissions under the baseline scenario.

**Methods**: Use module: *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*.

## Project Emissions

##### Task 3: (A) Ex-Ante Projection of GHG Pools and Emissions In the Project Scenario (Project Emissions)

Estimation of the carbon content of current pools and projection of carbon pools and emissions under the project scenario is undertaken using the following the steps:

***Task 3.1 Ex-ante soil restratification***

**Requirement**: Required for all projects.

**Goal**: To divide the project area into one or more strata within which the projected soil carbon pools and soil carbon dynamics are expected to be relatively uniform under the project scenario, given the stratification determined in Task 2.1, and the proposed treatment under the project scenario.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

***Task 3.2 Projection of treatment impacts per stratum, and effects on soil C pools***

**Requirement**: Required for all projects.

**Goal**: To project, for the time within the project crediting period, the changes in soil carbon pools which are expected to occur in each stratum within the project area, given the planned treatments for the stratum.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with soil carbon as the relevant variable *X*, and module *VMD0021 Estimation of Stocks in the Soil Carbon Pool.*

***Task 3.3 Ex-ante biomass re-stratification***

**Requirement**: Required for all projects where significant decreases in living biomass pools are expected to occur under the project scenario, as compared with the baseline scenario. Optional in all other circumstances.

**Goal**: To divide the project areainto one or more strata within which treatments are expected to result in living vegetation carbon pools and living vegetation dynamics which are relatively uniform for the full project crediting period.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with living biomass as the relevant variable *X.*

***Task 3.4 Projection of future aboveground woody and non-woody and below ground living biomass pools under the project scenario***

**Requirement**: Same as Task 3.3.

**Goal**: To project for the monitoringperiod the aboveground woody and non-woody biomass and belowground living biomass pools in each stratum based on expected treatment regimes, and to estimate the amount of livingbiomass carbon per unit area based on those projections.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with live biomass as the relevant variable *X* and the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*.

***Task 3.5 Projection of future wood harvest outputs under the project scenario***

**Requirement**: Required for all projects where the harvest of woody biomass within the project areais expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period and some or all of that woody biomass is used for the production of long lived wood products*.* Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional, but not recommended, where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario as compared with the baseline scenario*.*

**Goal**: To project for the monitoring period the amount of woody biomass harvesting which is expected to take place within the project area under the project scenario, and the percentage of that harvest which is expected to be used for the production of long lived wood products.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with wood harvest and wood utilization as the relevant variable *X.*

***Task 3.6 Projection of C sequestration in long lived wood products***

**Requirement**: Same as Task 3.5.

**Goal**: To estimate the amount of carbon which will be sequestered in long lived wood products under the project scenario, based on the projections prepared in Task 3.5.

**Methods**: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Task 3.5 as the inputs.

***Task 3.7*** ***Projection of future dead wood pools within the project area under the project scenario***

**Requirement**: Required where significant amounts of dead wood are found on the site at the project start date, and removals of dead wood through utilization, reduced inputs, or accelerated burning as part of a management activity, are expected to occur under the project scenario. Optional in all other circumstances.

**Goal**: To estimate the amount of biomass which will be sequestered in dead wood pools under the project scenario.

**Methods**: Use the module *VMD0019 Methods to Project Future Conditions*, with dead wood pools as the relevant variable *X*.

***Task 3.8 Projection of future domesticated animal populations under the project scenario***

**Requirement**: Required where increases in the emissions of GHGs from domesticated animal populations are expected under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for projected decreases in emissions from domesticated animals under the project scenario as compared with the baseline scenario.

**Goal**: To project the future populations of domesticated animals for the monitoring period under the project scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with domesticated animal populations as the relevant variable *X.*

***Task 3.9 Estimation of emissions of GHGs from domesticated animals within the project area under the project scenario***

**Requirement**: Same as Task 2.10.

**Goal**: To estimate the emissions of GHGs from the current and projected future populations of domesticated animals under the project scenario the monitoring period based on the projections prepared in Task 3.7.

**Methods**: Use module *VMD0027 Estimation of Emissions From Domesticated Animals*, with the outputs from Task 3.7 as the inputs.

***Task 3.10 Projection of future emissions of N2O or CH4 from the soils within the project area***

**Requirement**: Required where significant increases in the emissions of N2O or CH4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

**Goal**: To estimate future emissions from soils under the project scenario, in the case that these emissions are expected to increase.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0029 Estimation of Emissions of Non CO2 GHG From Soils*, as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils*, to estimate the projected future emissions.

***Task 3.11 Projected emissions from use of power equipment***

**Requirement**: Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be *significantly* greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

**Goal**: To estimate GHG emissions for the monitoring period from the use of power equipment under the project scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted for as a project emissions, whether or not they occur within the project boundary.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with fuel use in power equipment as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0030 Estimation of Emissions from Power Equipment*, to estimate the projected future emissions.

***Task 3.12 Projection of future litter pools***

**Requirement**: Required where *significant* decreases in the carbon content of the litter carbon pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

**Goal**: To estimate future litter pools under the project scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with litter carbon pools as the relevant variable *X.*

***Task 3.13 Projection of biomass consumption by fire***

**Requirement**: Required where *significant* burning is expected to be used for management of the project area under the project scenario. Optional but not recommended otherwise.

**Goal**: To project the future amounts of biomass consumed by fire during the project crediting period under the project scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with biomass consumed by fire as the relevant variable *X.*

**Task Notes**: This step shall be done twice if biomass burning is to be done both within the project area, and outside of the project areaas a consequence of displacement leakage. In that case, the results will be used for separate calculations during Task 3.16.

***Task 3.14 Projection of non CO2 emissions from burning***

**Requirement**: Same as Task 3.13.

**Goal**: To estimate emissions of non CO2 GHGs from burning of biomass.

**Methods**: Use module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils.*

**Task Notes**: This step shall be done twice if biomass burning is done both within the project area, and outside of the project areaas a consequence of activity shifting leakage. In that case, the results will be reported and accounted separately during Task 3.13 above.

***Task 3.15 Summation of ex-ante estimates and projections under the project scenario***

**Requirement**: Required for all projects.

**Goal**: To sum current and future carbon sequestration and emissions under the project scenario.

**Methods**: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*, setting leakage variables to 0, as these will be accounted for in section 8.3 below.

##### Task 4: (A) Ex-Post Accounting of GHG Pools and Emissions (Project Emissions)

Ex-post accounting of GHG pools and emissions must be undertaken prior to each verification event, and at least once every 5 years during the project crediting period. Note that where leakage mitigation measures include tree planting, agricultural intensification, fertilization, fodder production, and/or other measures to enhance cropland and/or grazing land areas, then any significant increase in GHG emissions associated with these activities must be accounted for using the relevant module, whether or not they occur within the project area, unless they are deemed not significant, or can otherwise be conservatively excluded.

***Task 4.1 Ex-post soil re-stratification***

**Requirement**: Required for all projects.

**Goal**: To divide the project area into one or more strata within which the soil carbon pools and soil carbon dynamics are relatively uniform at the time of sampling.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

***Task 4.2 Estimation of the carbon content of current soil carbon pools per unit of area, for each stratum***

**Requirement**: Required for all projects.

**Goal**: To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to allow estimation, at the required levels of statistical precision and accuracy, of the amount of soil carbon per unit area.

**Methods**: Use module *VMD0021 Estimation of Stocks in the Soil Carbon Pool.*

***Task 4.3 Ex-post living biomass re-stratification***

**Requirement**: Required for all projects where the aboveground woody and non-woody biomass and belowground living biomass carbon under the project scenario is found to be significantly less than that projected under the baseline scenarios at any time after the project start date. Optional under all other circumstances. Typically completion of this task will be required where the project area before the project start date contains more than scattered woody vegetation, and where the project activities include clearance, site preparation, burning or other activities likely to eliminate woody vegetation, or alternatively to enhance the recruitment of woody vegetation.

**Goal**: To divide the project area into one or more strata within which the vegetation carbon pools at the end of the project crediting period are relatively uniform.

**Methods**: Use module *VMD0018 Methods to Determine Stratification*, with above- and belowground living biomass stocks per unit area as the relevant variable *X.*

***Task 4.4 Estimation of the carbon content of aboveground woody and non-woody and below ground living biomass pools***

**Requirement**: Same as Task 4.3.

**Goal**: To sample the aboveground woody and non-woody biomass and below ground living biomass pools in each stratum to a sampling intensity sufficient to allow estimation to the required levels of statistical precision and accuracy of the amount of living biomass carbon per unit area.

**Methods**: Use module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass.*

***Task 4.5 Estimation of the amount of wood harvest from within the project area used for production of long lived wood products***

**Requirement**: Required for all projects where the harvest of woody biomass within the project area is expected to be *significantly* lower under the project scenario as compared with the baseline scenario at any time within the project crediting period, and some or all of that woody biomass is used for the production of long lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional but not recommended in the case where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario, as compared with the baseline scenario.

**Goal**: To estimate the amount of woody biomass harvesting taking place within the project area during a monitoring period.

**Methods**: Use module *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*.

***Task 4.6 Long Lived Wood Products***

**Requirement**: Same criteria as Task 4.5.

**Goal**: To project amount of carbon which will be sequestered in long lived wood products derived from harvesting from within the project area during the monitoring period.

**Methods**: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Task 4.5 as the inputs.

***Task 4.7 Estimation of dead wood pools within the project area***

**Requirement**: Required where dead wood is found on the site at the project start date, and *significant* removals of dead wood through utilization, reduced inputs, or accelerated burning as part of a management activity, are expected to occur under the project scenario.Optional under all other circumstances.

**Goal**: To estimate the current amount of biomass contained in dead wood pools.

**Methods**: Use module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*.

***Task 4.8 Estimation of current average domesticated animal populations within the project area***

**Requirement**: Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baseline scenario, due either to increases in populations or changes in feeding practices., Optional under all other circumstances.

**Goal**: To estimate the average current populations of domesticated animals within the project areaduring the monitoring period.

**Methods**: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*.

***Task 4.9 Estimation of emissions of GHGs from domesticated animals within the project area***

**Requirement**: Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baselines scenario, due either to increases in populations or changes in feeding practices. Not for use under all other circumstances, to conservatively ensure that crediting for reductions in emissions from domesticated animals does not occur.

**Goal**: To estimate the emissions of GHGs from the current populations of domesticated animals during the monitoring period.

**Methods**: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*, with the outputs from Task 4.8 as inputs.

***Task 4.10 Estimation of emissions from use of power equipment***

**Requirement**: Required for all projects where emissions from power equipment directly attributable to activities within the project area could be *significantly* greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

**Goal**: To estimate GHG emissions from the use of power equipment under the project scenario during the monitoring period.

**Methods**: Use module *VMD0030 Estimation of Emissions from Power Equipment*.

**Task notes:** Under this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted as a project emission, whether or not they occur within the project boundary.

***Task 4.11 Estimation of non CO2 emissions from burning***

**Requirement**: Required where *significant* burning has been used for management of the project area under the project scenario. Optional but not recommended under all other circumstances.

**Goal**: To estimate emissions of non CO2 GHGs from burning of biomass.

**Methods**: Use module *VMD0031 Estimation of Emissions from Biomass Burning*.

**Task notes**: This step must be done twice if biomass burning is done both within the project area and outside of the project area as a consequence of displacement leakage. In that case, the results will be reported and accounted separately during Task 4.15 and/or Task 4.16.

***Task 4.12 Monitoring and estimation of soil emissions of N2O or CH4 from within the project area***

**Requirement**: Required where *significant* increases in the emissions of N2O or CH4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

**Goal**: To estimate the emissions of N2O or CH4 from within the project area.

**Methods**: Use module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils*.

**Task notes**: These estimations are expected to be based on the same models as those used during the ex-ante project study, unless improvements in models have occurred in the interim. In either case, values of variables used in the models must be updated to reflect actual conditions which have occurred during the monitoring period. If an updated model is used, and if modeling of baseline emissions was done as part of the baseline study, that modeling must be redone using the improved models.

***Task 4.13 Estimation of current litter pools.***

**Requirement**: Required where *significant* decreases in the carbon content of the litter pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

**Goal**: To estimate the carbon content of the litter pool within the project area.

**Methods**: Use module *VMD0023 Estimation of Carbon Stocks in the Litter Pool*.

***Task 4.14 Summation of estimates of GHG fluxes under the project scenario***

**Requirement**: Required for all projects.

**Goal**: To sum carbon sequestration and emission impacts directly attributable to the project activity based on the monitoring undertaken during the monitoring period.

**Methods**: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*, setting leakage variables to 0, as these will be accounted in section 8.3 below.

## Leakage

Under the VCS rules GHG pools and emissions affected by leakage are projected both ex-ante and accounted ex-post. Note that projects must not account for positive leakage (ie, where GHG emissions decrease, or removals increase, outside the project areadue to project activities).

##### Task 3: (B) Ex-Ante Projection of GHG Pools and Emissions in the Project Scenario (Leakage)

***Task 3.16 Projection of leakage due to displacement of grazing, fodder and agricultural production***

**Requirement**: Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities are projected to decline within the project area due to project activities.

**Goal**: To project of future emissions from agricultural production, domesticated animals or fodder production displaced under the project scenario.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with displacement of domesticated animals or agricultural production as the relevant variable(s) *X.* Then, based on the outputs from this module, use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the module *VMD0032 Estimation of Emissions From Activity Shifting Leakage*, calculations of emissions may require the use of other modules.

***Task 3.17 Projection of leakage due to displacement of wood harvesting***

**Requirement**: Required for projects where displacement of wood harvest to areas outside of the project boundary is projected to occur.

**Goal**: To project future emissions from wood harvest displaced under the project scenario. Projection includes the reductions in emissions from these displaced wood harvest activities where they are expected to result in the production of long lived wood products.

**Methods**: Use module *VMD0019 Methods to Project Future Conditions*, with displacement of wood harvest as the relevant variable(s) *X.* Then, based on the outputs from this module, use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, calculations of emissions may require the use of other modules.

**Task notes**: Where wood harvesting occurs outside of the project boundary as a result of activity shifting leakage, and where that wood harvesting results in the production of long lived wood products, module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool* must be used to estimate the amounts of carbon stored in wood products resulting from the wood harvesting.

***Task 3.18 Projection of market leakage***

**Requirement**: Required for projects where reductions in the production of wood, animals or agricultural products within the project area are expected under the project scenario as compared with the baseline scenario, and where Tasks 3.16 and 3.17 do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area.

**Goal**: To project leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario.

**Methods**: Use module *VMD0033 Estimation of Emissions from Market Leakage*.

##### Task 4: (B) Ex-Post Accounting of Leakage from GHG Pools and Emissions (Leakage)

***Task 4.15 Monitoring and estimation of emissions from grazing, fodder and agricultural production displacement***

**Requirement**: Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities have declined within the project area due to project activities.

**Goal**: Estimation of emissions from domesticated animals or fodder production displaced as a result of project activities during the crediting period.

**Methods**: Use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the module, calculations of emissions may require the use of other modules.

***Task 4.16 Monitoring and estimation of emissions from wood harvest displacement***

**Requirement**: Required for projects where wood harvest occurred within the project area at the project start date, and where total wood harvest from the project area over the monitoring period will decline as compared with that projected under the baseline scenario.

**Goal**: Estimation of emissions from wood harvesting displaced as a result of project activitiesduring the crediting period.

**Methods**: Use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the, calculations of emissions may require the use of other modules. Where displaced wood harvesting results in the production of long lived wood products, module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, must also be used.

***Task 4.17 Estimation of market leakage***

**Requirement**: Required for projects where reductions in the production of wood, animals, or agricultural products within the project area have occurred under the project scenario, as compared with the baseline scenario, and where Tasks 4.15 and 4.16 do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area.

**Goal**: To estimate leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario.

**Methods**: Use module *VMD0033 Estimation of Emissions from Market Leakage*.

**Task notes**: If market leakage has been projected in Task 3, and if the input conditions remain the same ex-post as those predicted ex-ante, the projections completed in Task 3.14 may be used to satisfy the requirements of this task.

## Summary of GHG Emission Reduction and/or Removals

##### Task 4: Ex-Post Accounting of GHG Pools and Emissions (Net Emissions Reductions and/or Removals)

***Task 4.18* Calculation *of GHG emission reductions and/or removals***

**Requirement**: Required for all projects.

**Goal**: To summarize net greenhouse gas benefit of project activity.

**Methods**: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*.

**Task notes**: Net changes in atmospheric GHG at t=z can only be calculated ex-post.

# MONITORING

## Data and Parameters Available at Validation

Data and parameters available at validation are given in the modules associated with this methodology.

## Data and Parameters Monitored

Data and parameters available at validation are given in the modules associated with this methodology.

## Description of the Monitoring Plan

The monitoring plan must be prepared using module *VMD0034 Methods for Developing a Monitoring Plan*. This module includes specifications on quality assurance and quality control that must be followed during development of the project description and other project documents.

# REFERENCES AND OTHER INFORMATION

Specific references are given in the modules associated with this methodology.

### DOCUMENT HISTORY

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Comment** |
| v1.0 | 16 Nov 2012 | Initial version released |

# Appendix 6.0 The Regenerative Standard History

**Summary and Timeline**

**2010 – Earth Partners LLC, a wholly owned subsidiary of Applied Ecological Services (AES) was started by Steve Apfelbaum (AES), Will Raap, and Charlie Kireker with a mission to widely educate the public on the benefits of restoring soil health and soil carbon**

**2011 – Earth Partners LP (partnership between AES and Brinkman & Associates Reforestation) formed to bring further investment to the mission and writing begins on the Soil Carbon Quantification Method**

**2012 – Earth Partners LLC enter approval process with the Verified Carbon Standard (VCS), now Verra, and method is approved as VM0021 with all copyright / IP remaining with The Earth Partners LP. [Here](https://nam12.safelinks.protection.outlook.com/?url=https%3A%2F%2Fverra.org%2Fmethodologies%2Fvm0021-soil-carbon-quantification-methodology-v1-0%2F&data=05%7C02%7Csara%40aeinstitute.org%7C67863850966d4431a4d908dc482d5c3a%7C99a471b34b0f4026b89a4ad2727c07e9%7C0%7C0%7C638464606893274094%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=YOACS2No96KCdD8EJTn4Cnf7HfwTHqDcDEBQUAFnxLY%3D&reserved=0" \t "_blank) is the Verra page that shows that VM0021 was developed (and is copyrighted) by [The Earth Partners](https://nam12.safelinks.protection.outlook.com/?url=https%3A%2F%2Ftheearthpartners.com%2F&data=05%7C02%7Csara%40aeinstitute.org%7C67863850966d4431a4d908dc482d5c3a%7C99a471b34b0f4026b89a4ad2727c07e9%7C0%7C0%7C638464606893283399%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=vOEDTSukXZgq%2F4z2sM%2FrOHKxUuhySTi%2FGo39RrfOpQk%3D&reserved=0" \t "_blank).**

**Dec 2012 - Earth Partners LP and Earth Partners LLC part ways and Earth Partners LLC retains all for Soil Carbon Quantification Method / VM0021**

**Feb 2021 Resource Environmental Solutions (RES) purchases AES and Steve Apfelbaum retains the IP for VM0021.**

**March 2022 Verra inactivates VM0021**

**Sept 2022 Applied Ecological Institute, with science partners, updates VM0021 into a new protocol called ‘The Regenerative Standard SOC Module V1.0’ referring to many of the time-tested modules still available [online](https://verra.org/methodologies/vm0021-soil-carbon-quantification-methodology-v1-0/) for reference by project developers and VVBs.**

**Dec 2022 – The first SOC credits under The Regenerative Standard SOC V1.0 are verified and issued by [Nature’s Registry](https://public.validere.com/regen/projects).**

**May 2023 – The most recent version of The Regenerative Standard SOC V1.1 is released.**

**Ongoing – AEI, in partnership with Regen Network, is moving V2.0 through the peer review and public comment process prior to submitting to ICROA for accreditation. AEI is committed to continually improving the protocol maintaining the original vision set out by The Earth Partners LLC. The full story follows below.**

**Background--Origins and Lineage of The Regenerative Standard**

**Early Realizations**

A University of VT Gund Institute five-year, intersession, collaboratively taught course in Costa Rica on entrepreneurism and wetland mitigation brought together Will Raap, Steve Apfelbaum, John Todd and Robert Costanza with several dozen students annually at a remote Guanacaste province coastal community. Among many discussions, the debate was fiercest about whether the focus of climate mitigation should be on planting more trees or rebuilding soil health on earth. Will consistently brought us to the conclusion that focusing on afforestation and reforesting missed a key opportunity on earth, soil health. We decided at that moment that we both wanted to leverage more interest in improving soil health on earth using photosynthesis and soil microbial life to rebuild soil system health worldwide.

**Commitments to bring Soil Carbon understandings to the Fore.**

**The Earth Partners, LLC** began with a focus on achieving a wider, more accurate understanding of soil carbon. Steve Apfelbaum led the writing about this need including grant proposals to secure funding to accelerate the conversation. Early efforts started with a meeting with USDA, NRCS and learned of a grant proposal opportunity to fund addressing the key data gaps.

During this time, Will brought other potential investor partners to the table while Steve connected with soil health and soil carbon academics and researchers. On their return to the states, Charley Kireker of Fresh Tracks Capital quickly joined the effort. Word spread and we discovered great interest in helping in the education and increased awareness needed.

The group organized several strategic planning meetings with diverse stakeholders to discuss science gaps, marketplace gaps, and widespread misunderstandings about soil health and soil carbon, and the role they could play in climate mitigation and fostering a regenerative agricultural future. This process revealed a wealth of standardized scientific measurement methods and metrics but the information was siloed and scattered and none focused on how to structure an incentive system that encouraged activity changes and monitoring measure to measure improvements over time. We decided that the modeling was too early, too speculative and would not create a trustable, transparent, robust, and defensible method around which consensus could be achieved among disparate counterparties, environmentalists, industry groups, farmers, and the federal trade commission, among others.

We also learned that there was a fundamental misunderstanding and mythology about soil carbon and soil health. In an effort to bring clarity and scientific rigor, Steve’s company at the time, Applied Ecological Services, Inc. (AES), became involved with a consortium of eighteen research institutions who were working with soil carbon in agricultural (primarily cropped) landscapes. AES and The Earth Partners also became involved with researchers studying soil carbon in peatlands, non-peat wetlands, and in rangelands across the world. Over a year of conversations, site visits, and documenting science conclusions, data gaps and mythology (that lived as an undercurrent with both academics and laypersons) we decided creating a standard method for measurement, referencing the most rigorous science at the time was necessary. Over the course of six months we designed the “Soil Carbon Quantification Method.” Steve focused on the soil carbon and the Robert Seaton of the Brinkman Group focused on forest carbon. A circulated draft of the method was reviewed multiple times by a distinguished team of soil carbon specialists with requisite refinements completed by The Earth Partners.

**Evaluating the Soil Carbon Quantification Method**

Top soil carbon scientists in the USA, Costa Rica, Chile, and Brazil began testing The Soil Carbon Quantification Method in the highest quality natural areas and working forest and agricultural lands. We collaborated on testing the method with the World Resources Institute and The Nature Conservancy as part of an effort to discover climate mitigation benefits on 6000-acre cropland to prairie restoration in Indiana. All tests affirmed the need for measurements as the existing models were 1-2 orders of magnitude in error of the carbon stocks measured in the field.

With the field assistance of Dr John Kimble (ARS, USDA soil scientist) we worked with Dr Dan Janzen (Dry tropical Savanna Foundation) and Alvaro Ugalde (Director of CR Park Service) to sample soil carbon in several national parks and the dry tropical savanna foundation lands. Working with Doug and Kris Tompkins and Fundacion Patagonica, we sampled reference natural areas in Valle Chaka Buko in Patagonia Chile and Rincon del Socorro (in Northern Argentina). We continued to revise the method after a year of field testing, sampling and findings.

In 2011 AES submitted a [USDA NRCS Conservation Innovation Grant proposal](https://cig.sc.egov.usda.gov/projects/agricultural-soil-carbon-palouse-region-developing-large-scale-agricultural-soil-carbon) focused on landscape scale sampling of soil carbon stocks over the Palouse agro-ecosystem in eastern Washington State, northern Idaho, and southeastern Oregon. The purpose of the study was to evaluate and refine the method for large scale market-making possibilities with the regenerative producers of Sheperd’s Grain. The landscape biophysical stratification process was developed and field tested by soil scientists Dr David Hammer and Dr Thomas Hunt, landscape ecologist S. Apfelbaum and field operation specialists from AES focused on cost effective, safe and accurate measurement of carbon stock improvements. AES, and then with subsequent partner Native Energy, engaged the farmers in carbon improvement contracts and all worked together to value and attempt to monetize the measured improvements. This program robustly measured soil carbon using chrono series analysis and parallel repeated sampling over a decade. Predicted significant and reliable improvements in soil carbon by the chrono series analysis and resampling showed a reliable 2 TCo2e/acre-yr accrual rate over this large landscape on farms using “Low Disturbance Farming” practices which involve >80% crop residue retainage and <20% soil disruption from trash rakes on no-till and one pass no-till. The improvements at a meter depth were significant 1.

While working on the Palouse project, our collaboration with the best soil carbon scientists in the world, revealed the need for a publication to support and inform industry and politicians on potential climate policy; specifically on the role of healthy soils and soil carbon improvements connection to climate mitigation. This collaboration resulted in the book [Soil Carbon Management – Economic, Environmental and Societal Benefits](https://a.co/d/feaLQ8U), published by CRC press in 2007. While writing the book, we shared data from the projects and received informal and formal technical peer reviews from thirty-five of the top scientists and early evolving climate mitigation market experts. This peer review, which included multiple US academics and recognized experts in the UK and across the world, refined the science and informed the final revision of the method which we submitted to VCS formal review and validation.

**Commercializing The Soil Carbon Quantification Method**

In 2012, the Earth Partners submitted the method for approved use under the newly developed Verified Carbon Standard (VCS), now Verra. From the original philosophy and subsequent scientific findings, we also wrote the requisite front-end modules, eligibility sections, additionality sections, etc. and successfully navigated the technical and marketplace peer review process. After a year, we emerged from the required double technical peer review/validation process, and the method was approved as VM0021.

Soon after the approval, The Earth Partners LP and Earth Partners LLC parted ways due to a shift in focus by The Earth Partners LP. AES/The Earth Partners LLC retained copyright and all IP and expanded the focus to address quantifying soil carbon and climate health. AES/The Earth Partners LLC worked on tens of millions of acres using VM0021 and learned many things including: sampling costs become de minimus when working at landscape scale and repeated sampling could accurately document statistically significant improvements in Total Carbon and Soil Organic Carbon within a few years in productive landscapes with appropriate practices and slightly more time in arid and less productive lands. We learned that grazing and improved farming practice changes, land restoration, and mined land reclamation could produce reliable improvements.

Working with the [Shell Oil GameChanger](https://www.shell.com/what-we-do/technology-and-innovation/innovate-with-shell/shell-gamechanger.html) program, Russ Conser at Shell, grazing specialist Dr Richard Teague at Texas A & M, film producer Peter Byck at ASU and a diverse research team including scientists from AES, deployed Verra VM0021 on a Shell Canada study and a Southeastern US study of soil carbon change under improved grazing practices. The findings of the SE study became the focus of the Carbon Nation Series’: [Carbon Cowboys](https://www.carboncowboys.org/),” and “[Roots so Deep](https://rootssodeep.org/)” which have gained global attention and catapulted proponents of improved grazing (e.g., Dr Allen Williams, Gabe Brown of Understanding Agriculture) in front of the increasing interest by farmers and ranchers. Our study findings were enlightening, especially the soil carbon findings and this drew attention and allowed us to present our findings to many groups, agencies, and Obama’s Office of Science and Technology Team.

Many publications highlighted the rigor of VM0021: [Carbon Management: Quantifying carbon for agricultural soil management](https://www.tandfonline.com/doi/full/10.1080/17583004.2019.1633231), [EDF: Agricultural Soil Carbon Credits: Making sense of protocols for carbon sequestration and net greenhouse gas removals.](https://www.edf.org/sites/default/files/content/agricultural-soil-carbon-credits-protocol-synthesis.pdf), but no credits were generated as many developers gravitated towards less rigorous protocols that did not have the same sampling requirements. In 2019 AES was approached by an organization with aspirations to deliver soil carbon crediting opportunities to the farming community at large scales. In the end, this group chose to focus on modeling with reduced and minimal sampling that would not meet the requirements of Verra VM0021. A new protocol Verra VM0042, which does not require as robust sampling requirements, became Verra’s primary soil carbon quantification protocol and VM0021 was deactivated in March 2022.

Responding to demand signals from offset buyers wanting (and willing to pay more for) more scientifically robust soil organic carbon credits, Applied Ecological Institute, founded by Steve Apfelbaum, updated VM0021 as part of a new suite of open access protocols called [The Regenerative Standard](https://regenerativestandard.org/) (The Standard). The mission is to provide rigorous, straight-forward protocols for nature-based solutions and accelerate nature-positive climate action at scale. Following nature’s example of an integrated systems approach, The Standard contains three separate protocols: Soil Organic Carbon (SOC), Biodiversity and Water that are purpose built to work synergistically to improve degraded ecosystems. [SOCV1.1](https://regenerativestandard.org/wp-content/uploads/2023/08/Regenerative-Standard-v1.1-8.14.23.pdf?) was the first to be deployed and carbon project developers have, thus far, implemented this protocol to generate carbon credits on roughly 600,000 acres to date. Pricing for the offtakes is not public, but the project developers report higher than average pricing for the high-quality credits.

The Regenerative Standard will be continuously reviewed and improved including seeking accreditation in 2024.

1. Steven I. Apfelbaum\*, Fugui Wang and Ry Thompson, Soil Organic Carbon Changes under Low Disturbance Cropping in the Upper Columbia Plateau Region of Washington, Idaho, and Oregon, USA. Open Acc J Envi Soi Sci 6(3) - 2022. OAJESS.MS.ID.000239. DOI: 10.32474/OAJESS.2022.06.000239

# Appendix 7.0 Verra Links

[VM0026](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf) *[Methodology for Sustainable Grassland Management (SGM), v1.1](https://verra.org/wp-content/uploads/imported/methodologies/VM0026-Methodology-for-Sustainable-Grasslands-Management-v1.1.pdf)*

[VM0042](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf) *[Methodology for Improved Agricultural Land Management, v2.0](https://verra.org/wp-content/uploads/2023/05/VM0042-Improved-ALM-v2.0.pdf)*

[TRS-1](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/) *[Methods to Determine Stratification, v1.0](https://verra.org/methodologies/vmd0018-methods-to-determine-stratification-v1-0/)*

[TRS-2](https://verra.org/methodologies/vmd0019-methods-to-project-future-conditions-v1-0/) *[Methods to Project Future Conditions, v1.0](https://verra.org/methodologies/vmd0019-methods-to-project-future-conditions-v1-0/)*

[TRS-3](https://verra.org/methodologies/vmd0020-methods-to-determine-project-boundaries-v1-0/) *[Methods to Determine the Project Boundary, v1.0](https://verra.org/methodologies/vmd0020-methods-to-determine-project-boundaries-v1-0/)*

VMD0021\*\* *Estimation of Stocks in the Soil Carbon Pool, v1.0*

[TRS-4](https://verra.org/methodologies/vmd0022-estimation-of-carbon-stocks-in-living-plant-biomass-v1-0/) *[Estimation of Carbon Stocks in Living Plant Biomass, v1.0](https://verra.org/methodologies/vmd0022-estimation-of-carbon-stocks-in-living-plant-biomass-v1-0/)*

[TRS-5](https://verra.org/methodologies/vmd0023-estimation-of-carbon-stocks-in-the-litter-pool-v1-0/) *[Estimation of Carbon Stocks in the Litter Pool, v1.0](https://verra.org/methodologies/vmd0023-estimation-of-carbon-stocks-in-the-litter-pool-v1-0/)*

[TRS-6](https://verra.org/methodologies/vmd0024-estimation-of-carbon-stocks-in-the-dead-wood-pool-v1-0/) *[Estimation of Carbon Stocks in the Dead Wood Pool, v1.0](https://verra.org/methodologies/vmd0024-estimation-of-carbon-stocks-in-the-dead-wood-pool-v1-0/)*

[TRS-7](https://verra.org/methodologies/vmd0025-estimation-of-woody-biomass-harvesting-and-utilization-v1-0/) *[Estimation of Woody Biomass Harvesting and Utilization, v1.0](https://verra.org/methodologies/vmd0025-estimation-of-woody-biomass-harvesting-and-utilization-v1-0/)*

[TRS-9](https://verra.org/methodology/vmd0027-estimation-of-domesticated-animal-populations-v1-0/) *[Estimation of Domesticated Animal Populations, v1.0](https://verra.org/methodology/vmd0027-estimation-of-domesticated-animal-populations-v1-0/)*

[TRS-8](https://verra.org/methodology/vmd0026-estimation-of-carbon-stocks-in-the-long-lived-wood-products-pool-v1-0/) *[Estimation of Carbon Stocks in the Long Lived Wood Products Pool, v1.0](https://verra.org/methodology/vmd0026-estimation-of-carbon-stocks-in-the-long-lived-wood-products-pool-v1-0/)*

[TRS-10](https://verra.org/methodology/vmd0028-estimation-of-emissions-from-domesticated-animals-v1-0/) *[Estimation of Emissions from Domesticated Animals, v1.0](https://verra.org/methodology/vmd0028-estimation-of-emissions-from-domesticated-animals-v1-0/)*

[TRS-11](https://verra.org/methodology/vmd0029-estimation-of-emissions-from-non-co2-ghgs-from-soils-v1-1/) *[Estimation of Emissions of Non-CO2 GHG from Soils, v1.1](https://verra.org/methodology/vmd0029-estimation-of-emissions-from-non-co2-ghgs-from-soils-v1-1/)*

[TRS-12](https://verra.org/methodology/vmd0030-estimation-of-emissions-from-power-equipment-v1-0/) *[Estimation of Emissions from Power Equipment, v1.0](https://verra.org/methodology/vmd0030-estimation-of-emissions-from-power-equipment-v1-0/)*

[TRS-13](https://verra.org/methodology/vmd0031-estimation-of-emissions-from-burning-v1-0/) *[Estimation of Emissions from Burning, v1.0](https://verra.org/methodology/vmd0031-estimation-of-emissions-from-burning-v1-0/)*

[TRS-14](https://verra.org/methodology/vmd0032-estimation-of-emissions-from-activity-shifting-leakage-v1-0/) *[Estimation of Emissions from Activity-Shifting Leakage, v1.0](https://verra.org/methodology/vmd0032-estimation-of-emissions-from-activity-shifting-leakage-v1-0/)*

[TRS-15](https://verra.org/methodology/vmd0033-estimation-of-emissions-from-market-leakage-v1-0/) *[Estimation of Emissions from Market Leakage, v1.0](https://verra.org/methodology/vmd0033-estimation-of-emissions-from-market-leakage-v1-0/)*

[TRS-16](https://verra.org/methodology/vmd0034-methods-for-developing-a-monitoring-plan-v1-0/) *[Methods for Developing a Monitoring Plan, v1.0](https://verra.org/methodology/vmd0034-methods-for-developing-a-monitoring-plan-v1-0/)*

[TRS-17](https://verra.org/methodology/vmd0035-methods-to-determine-the-net-change-in-atmospheric-ghg-resulting-from-project-activities-v1-0/) *[Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities, v1.0](https://verra.org/methodology/vmd0035-methods-to-determine-the-net-change-in-atmospheric-ghg-resulting-from-project-activities-v1-0/)*

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# Appendix 8.0 Migrating from TRS Version 1.0 to 2.0

**TRS Version 1.0 was designed to create an important on-ramp** for accelerating and helping rapidly scale participation by farmers, ranchers, conservation landowners, and other landowners to improve their land, soil, water, biodiversity functions and benefitting from new revenues they might have access to through measurable improvements recognized and rewarded by new markets.

Focus groups that we conducted or participated in found that most generational transitions in land ownership in ranch and farm families, and even conservation landowner estates, and the family estate planning this required, reduced or prevented these landowners entering into these markets with long term commitments. For this reason, we recognized TRS Version 1.0 as an on-ramp that landowners could engage and become familiar and comfortable with these new markets. By design, the on-ramping strategy resulted in a rolling contract period, allowing re-enrollment, for multiple cycles under the same activity. A rolling 5-year contract period was being used by early project developers with annualized verification and payments to ranchers and farmers. Because soil carbon was so very depleted on most farms and ranches, the principles of a rolling contract period was understood well by early adopter landowners and their neighbors who observed the benefits of the practice change and learned about the economic benefits to the enrollees. We included a 15-year tail for maintenance of the practice change that would start the year the landowner decided not to re-enroll in the program. During this 15-year period, monitoring would be required, annualized payments at some level were offered by the project developer and annual verification, review and issuance of credits by Nature’s Registry was to occur.

**The Regenerative Standard Version 2.0 is** designed to **deliver** longer-term assurances of the benefits offered by nature-based solutions, especially from soil carbon restoration projects, to address climate mitigation needs. This program, requires a minimum 40-year tail, and invites participation by farmers, ranchers, conservation landowners, and other landowners to improve their land, soil, water, biodiversity functions, allowing them to benefit from new revenues they might have access to through measurable improvements recognized and rewarded by this minimum 40 yr term commitment, and longer term options including perpetually securing carbon sequestration for the markets.

While Versions 1 and 2 of The Regenerative Standard allow enrollees to renew their land in the soil carbon program as long as measurable improvements in soil carbon continues. Version 2 requires a minimum 40-year monitoring tail during which annual monitoring and a buffer pool are required for the term. Project developers are required to continue monitoring annually during the crediting and post-crediting 40 year monitoring period. As with Version 1.0, annual monitoring is reported and verified during the crediting period, and also reported and verified during the post-crediting monitoring period. During the post-crediting monitoring period, no significant change in activity on the land must be demonstrated in the annual monitoring report. This is evidence that the measure-to-measure SOC improvements documented during the project crediting period have been maintained during the monitoring period. If a proponent wishes to augment crediting period measurements by repeating standard procedures to obtain ongoing measurements of SOC stocks during the monitoring period, or by use of with emerging technology data (e.g. Flux tower data, etc) to provide additional evidence that SOC stocks have not declined, this can provide unequivocal evidence of the protection required during the monitoring period.

This on-ramping by use of Version 1.0 is working. Increased interest by ranchers and farmers on the benefit of migrating to being enrolled under TRS Version 2.0, necessitates clarification. To consummate this change, the project developer would have to:

* + - 1. Revise the PDD to demonstrate the 40-year post-crediting minimum period for monitoring and documenting the project activity period by the landowner.
      2. The revised PDD would need to include the updated contract with the landowner documenting their commitment to this change in timeline.
      3. A rolling contract re-enrollment period can still be used as long as the 40-year timeline for monitoring is memorialized in the revised PDD and the documents for re-enrollment and contract with the landowner. We see no reason that properties wishing to convert from Version 1 to Version 2 requirements could not continue under the same five (5) year rolling contact period but with the addition of the 40-year monitoring requirement after re-enrollment ceases.
      4. The project developer must revise in their PDD the needs assessment and revise their buffer pool insurance agreement with Nature’s Registry for each enrolled participating project, and landowners or leaseholder, in the program.
      5. Projects registered under Version 1 can convert to Version 2 at any time under mutual agreement of the landowners and project proponent with notification provided to TRS and Nature’s Registry. Accompanying this change must be the updated contract, updated PDD that reflects the 40-yr minimum post-crediting monitoring period, adjusted buffer pool contribution justification to meet this 40-year buffer pool life, and the revised monitoring and reporting plan and program survival assurance for the 40-year period, plus for any additional crediting period project life.

**Summary**

As of the end of 2024, project developers using The Regenerative Standard V1.0 have succeeded in enrolling more than 1 million acres of ranch lands and farmlands, and enrollment continues to grow in scale. It has met farmers and ranchers where they are at with their family, land and financing while creating a durable program to ensure family tenure of the farm, ranch, conservation lands.

We believe some program certification processes will not accept TRS Version 1.0 enrolled farmers and ranchers even through the effective timeline for their involvement may well exceed 40 years during active crediting and another 10 years of post-crediting monitoring. We understand this and feel the Version 1.0 on-ramping function to be valuable enough to building program confidence in the landowner community that it will help accelerate scaling up ranchers/farmers wishing to move toward the longer-term commitment requirements under Version 2.0.

The Regenerative Standard will move to certifying TRS Version 2.0 Soil carbon quantification method. If certifying agents recognize the value of the on-ramping stair-step function and how V.1.0 and V.2.0 may function to scale overall acreage involved in improvements, perhaps this could be a benefit in the future to the TRS V1.0 enrollees.

**Attachment 9. Monitoring Period Funding for Monitoring Permanence and Protection for Reversals**

**Introduction**

Shortfalls and reversals of credit, during the crediting period for each property is to be addressed as a part of the buffer pool development program under The Regenerative Standard for the entire tenure of crediting (See Permanence Sections of TRS).

For planning and funding for reversals occurring after the crediting period at each project site, the project developers must provide a plan for long-term monitoring and corporate succession and full funding assurances to underwrite monitoring.

This protocol establishes a monitoring buffer pool to meet the crediting period needs to address reversals and shortfalls. Under TRS Version 1.0 this is specifically to address the crediting period duration prior to the 10-year monitoring period. Under TRS Version 2.0 the same crediting period duration buffer pool must be documented, verified, and accepted by Nature’s Registry prior to credit issuance by Nature’s Registry.

Below is the framework for funding the reversal buffer pool for the post-crediting period under TRS Version 2.0 which requires a minimum of 40 years. The same framework below would be used for determining the funding needs for a post-crediting longer time commitments that may include 100 years, 1000 years or a perpetual commitment.

This framework and requirements help a project developer and landowner to understand the TRS requirements for ensuring adequate funds are available for the selected post-crediting timeline and commensurate monitoring needs. This same framework results in The Regenerative Standard having in place and coordinated between all parties, the creation of a successful durable buffer pool for Nature's Registry to backstop reversals and shortfalls over the entire life of each project.

1. During the life of the crediting period, and again at the end of the crediting period the project developer must update or complete the permanence risk assessment using the permanence risk worksheet in TRS V2.0.
2. During the life of the crediting period for each project, the project proponent must annually reassess and complete and provide updates in the Permanence risk assessment worksheet. The updated worksheet shall annually accompany submittals to a verifier and credit requests. The verifier shall confirm as a part of the annual verification process and verification reporting, and Nature’s Registry shall review for concurrence, said Permanence risk assessment worksheet findings.
3. During the crediting life of each property or at the project level, as a part of the annual record of submittals, documentation, verification and Nature’s Registry review, certification and credit issuance, this risk assessment worksheet will be used to adjust up, when and if the summary suggests increased risks from the earlier assessments has occurred. The Risk assessment worksheet will be used by the project proponent to adjust costs and this in turn will result in an increased annual (during the property/project crediting life) funding need to the Nature’s Registry buffer pool by the project proponent.
4. The following are the on-going requirements during each of the 40 years after the last crediting years.
   1. Annual monitoring to confirm project land management and land use activity has occurred each year.
   2. Annual monitoring report documents protection of soil carbon stocks can also be demonstrated by remeasurement or use of emerging technologies (e.g. Flux tower measurements, remote sensing of land cover and standing crop biomass consistency, etc.).
5. Annual report must be submitted to Nature’s Registry which must include confirmation on activity continuity and/or confirmed protection of carbon stocks is demonstrated.
6. Verifier must review the monitoring report and issue to the project proponent and Nature’s Registry a verification report that the monitoring report has been completed to the standards and content requirements, with recommendations on acceptance or a need for the project proponent to submit a mitigation and reconciliation plan.

**BUFFER POOL ASSURANCE OPTIONS**

This framework and these requirements help a project developer and landowner to understand the TRS requirements for ensuring that adequate funds are available for the selected post-crediting timeline and commensurate monitoring needs. This same framework results in Nature’s Registry having in place the creation of a successful durable buffer pool to backstop reversals and shortfalls over the entire life of each project.

**TRS V.1-10 year monitoring period**

At end of crediting period, a 5%/year buffer draw down rate will be established and the drawn down credit will be made available to the project developer. The developer may sell those credits each year to use for landowner payments, monitoring fees, and verification reports. As an example, if there are 100,000 credits in a project developers buffer pool, 5,000 may be drawn down per year, once a yearly monitoring report is delivered, verified and a verification report is approved and credits, including draw down credits are certified and issued, and upon receipt of a payment fee to Nature’s Registry. At the end of 10 years, the remaining 50% of credits will convert to a Programmatic Buffer to be used to satisfy any program-wide reversals.

**TRS V.2-40 year minimum Monitoring Period**

At the end of the crediting period, a 1.5%/year buffer draw down rate will be established. As an example, if there are 100,000 credits in the buffer pool, 1,500 credits may be drawn down per year after an annual monitoring report is reviewed and verified by a verifier and the drawn down credits are certified and a payment of a fee for the draw down credits are issued by Nature’s Registry. Developer may sell those credits each year to use for landowner payments, monitoring fees, and verification reports. At the end of 40 years, the remaining 40% of credits in the buffer pool will convert to a Programmatic Buffer to be used to satisfy any program-wide reversals.

**TRS V.2-100 to Perpetual Monitoring Period**

At the end of the crediting period, a 1%/year buffer draw down rate will be established. As an example if there are 100,000 credits in the buffer, 1,000 credits may be drawn down per year after an annual monitoring report is reviewed and verified by a verifier and the drawn down credits are certified and draw down credits are issued by Nature’s Registry. Developer may sell those credits each year to use for landowner payments, monitoring fees, and verification reports, and payment for the drawn down credits to Nature’s Registry.

For a perpetual commitment of a project, via a permanent easement or deed restriction, the developer may work with the Nature’s Registry to utilize the value of the remaining buffer pool credits to establish an endowment or other funding for the easement enforcing organization, and for management, monitoring, measurement related science for the property.

**Procedures**

A simple standard annual monitoring report, a simplified verifier checklist confirming the activity has not changed will both greatly reduce the costs of monitoring during the forty years, or other elected duration. We encourage on-the-ground calibration and confirmation tied to temporal and spatial remote sensing that can be used to cover large acreages for purposes of confirmation.

If a functionary organization is doing the monitoring, including Nature’s Registry, it can deploy remote sensing methods (e.g. Stratifyx APP) with just in time digital satellite and/or aerial imaging to document and measure that conditions of vegetation cover, bare soil, and graminoid/woody vegetation or C3/C4 vegetation composition during any monitoring year has not deviated in a way that would indicate depletion or decline in the condition last measured on the land.

**For the “Buffer Pool Assurance Options” the Project developer must disclose which TRS Version that they have used, and meet both the crediting period buffer pool requirements of TRS V 1.0 and/or TRS V 2.0. They also must document their election on the timeline commitment under TRS V 2.0, and the plans for creation of the buffer pool for said time duration.**

1. *Nature’s Registry*is an independently developed, operated, and curated ledger that has been designed to work with regenerative, restorative, and conservation projects, managed by an independent organization and board of advisors. [↑](#footnote-ref-2)
2. **(See White Paper Compendium on SOC tenure risks on Applied Ecological Institute web site: <https://www.aeinstitute.org/resources-1>).**  [↑](#footnote-ref-4)
3. 1 Derived from Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation, author Lucio

   Pedroni, now consolidated in VCS Methodology *VM0015 [Methodology for Avoided Unplanned Deforestation](http://www.v-c-s.org/methodologies/VM0015)*

   [↑](#footnote-ref-5)
4. 2 Derived from Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation, author Lucio Pedroni, now consolidated in VCS methodology VM0015 Methodology for Avoided Unplanned Deforestation [↑](#footnote-ref-6)
5. GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,49 (GOFCGOLD Project Office, Natural Resources Canada, Alberta, Canada) [↑](#footnote-ref-7)
6. The trade-off of merging classes is that carbon estimates will be subject to a higher degree of variability. [↑](#footnote-ref-8)
7. 5 See Angelsen and Kaimowitz (1999) and Chomiz *et al*. (2006) for comprehensive analysis of deforestation agents and drivers as an example. [↑](#footnote-ref-9)
8. GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,

   (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada) (http://www.gofc-gold.unijena.de/redd/sourcebook/Sourcebook\_Version\_July\_2009\_cop14-2.pdf). [↑](#footnote-ref-10)
9. Refers to GPG LULUCF Equation 4.3.1 [↑](#footnote-ref-11)
10. Example Table 3A.1.8 in GPG LULUCF 2000 (http://www.ipccnggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/Chp3/Anx\_3A\_1\_Data\_Tables.pdf), or **P.E.** Levy \*, S.E. Hale and B.C. Nicoll, 2004, Forestry, 77 (5): 421-430, Biomass expansion factors and root : shoot ratios for coniferous tree species in Great Britain. [↑](#footnote-ref-12)
11. Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce CH4, although ruminants are the largest source since they are able to digest cellulose, due to the presence of specific micro organisms in their digestive tracts. The amount of CH4 that is released depends on the type, age, and weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal. [↑](#footnote-ref-13)
12. Refer to equation 10.19 and equation 10.20 in IPCC 2006 GL AFOLU or equation 4.12 and equation 4.13 in GPG 2000 for agriculture. [↑](#footnote-ref-14)
13. Refer to equation 10.22 in AFOLU volume of the IPCC 2066 Guidelines or equation 4.15 in GPG 2000 for agriculture. [↑](#footnote-ref-15)
14. Refer to equations 10.25, 10.26 and 10.27 in AFOLU volume of the IPCC 2006 Guidelines and/or equation 4.18 in GPG 2000 for agriculture. [↑](#footnote-ref-16)
15. IPCC (2000) Good practice guidance LULUCF and IPCC (1996) Revised Guidelines for National Greenhouse Gas Inventories, IPCC (2006) Guidelines for National Greenhouse Gas Inventories [↑](#footnote-ref-17)
16. Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental

    Policy Solutions [↑](#footnote-ref-18)
17. Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental

    Policy Solutions [↑](#footnote-ref-19)
18. Refers to table 4-17 and table 4-18 in 1996 IPCC Guideline [↑](#footnote-ref-20)
19. Refers to Equation 3.2.18 in IPCC GPG-LULUCF, Equation 4.22 and Equation 4.23 in GPG-2000 [↑](#footnote-ref-21)
20. Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF (http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch5wb1.pdf page 20 (visited 18-05-2010)and Equation 3.2.19 in GPG LULUCF [http://www.ipcc-](http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_2_Forest_Land.pdf)

    [nggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/Chp3/Chp3\_2\_Forest\_Land.pdf;](http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_2_Forest_Land.pdf) page 27 (visited 18-05-2010) [↑](#footnote-ref-22)
21. Available on the VCS website. [↑](#footnote-ref-23)
22. Available on the CDM website. [↑](#footnote-ref-24)