

METHODOLOGICAL DOCUMENT AFOLU SECTOR

BCR0009 SOIL ORGANIC CARBON
(SOC) stock increase by adding high
organic content from anaerobic digestate

BIOCARBON CERT[®]

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Documento for public consultation

Terms, definitions and acronyms

AD	Anaerobic digestion
Anaerobic digestate	Is the liquid or solid material processed through anaerobic digestion. Labeling digestate materials shall be designated by prefixing the name of the feedstock from which it is produced, i.e., cow manure digestate, biosolids digestate, etc.
Additionality (SOC)	<p>The condition whereby the net increase in SOC stocks is demonstrably attributable to the project activity and would not have occurred in the absence of carbon crediting incentives, as determined in accordance with the BioCarbon Baseline and Additionality Tool.</p> <p>SOC increases resulting from legally required practices, common practice, or existing incentive schemes shall not be considered additional.</p>
Agroecosystem	Are the ecosystems supporting the food, fiber and other production systems in farms and gardens.
Avoiding Double Counting	The principle whereby SOC removals credited under this methodology are not simultaneously claimed, credited, or accounted for under another carbon crediting mechanism, compliance system, or national greenhouse gas inventory without appropriate adjustments, in accordance with the BioCarbon Avoiding Double Counting Tool.
C	Carbon
CO₂	Carbon dioxide.
CO_{2-e}	Carbon dioxide equivalent.
CT	Conventional tillage.
Digestate	Is a physical output of the anaerobic digestion (AD). It can be a liquid or solid depending on the digestion technology employed and postprocessing (e.g., dewatering, drying, pelletizing).
DAI	Defined area of intervention.
DBD	Dry bulk density.
DM	Dry matter.
EPrA	Eligible project area.

GHG	Greenhouse gas.
Baseline SOC Scenario	<p>The scenario representing the continuation of pre-project land management practices and associated SOC stock dynamics in the absence of the project activity.</p> <p>The baseline SOC scenario shall exclude short-term variability driven by climatic conditions, natural soil processes, or measurement uncertainty.</p>
GHG – PDs (Greenhouse gas project developer)	Individual or organization that has overall control and responsibility for a GHG project.
GHG project (Greenhouse gas project)	A set of measures ensuring the reduction (prevention) of greenhouse gas emissions or an increase in the absorption of greenhouse gases.
GWP_{N₂O}	Global Warming Potential for N ₂ O, kg-CO _{2-e} (kg-N ₂ O) ⁻¹ .
HC	Humic carbon
IAs	Intervention areas.
Leakage (SOC)	An increase in greenhouse gas emissions or a decrease in carbon stocks outside the project boundary that is attributable to the implementation of the project activity, including displacement of land management practices or activity shifting.
LMSP	Land management sustainable practices.
Monitoring	Continuous or periodic evaluation of GHG emissions, GHG removals, or other GHG-related data.
N₂O	Nitrous oxide.
NT	No tillage
OM	Organic matter.
Org-N	Organic nitrogen.
Permanence	The degree to which credited SOC removals are maintained over time, acknowledging that SOC is inherently subject to potential reversal due to changes in land management, disturbance events, or other anthropogenic or natural factors.

PTF	Pedotransfer functions.
Reversal	<p>Any measurable decrease in credited SOC stocks relative to the level previously achieved and credited under the project activity, regardless of cause.</p> <p>Reversals may be intentional or unintentional and shall be addressed through the permanence and reversal risk management provisions of the BioCarbon Standard.</p>
RMWN₂O	Ratio of molecular weights of N ₂ O and N (44/28), tonne-N ₂ O (t-N) ⁻¹ .
RMWCO₂	Ratio of molecular weights of CO ₂ and C (44/12), tonne-CO ₂ (t-C) ⁻¹ .
SALM	Sustainable agriculture land management.
SC	Soil carbon
Soil Organic Carbon (SOC)	<p>The organic carbon component of soil, expressed as mass of carbon per unit area or volume, whose changes over time are attributable to land management practices.</p> <p>For the purposes of this methodology, SOC refers exclusively to anthropogenic increases in soil carbon stocks resulting from eligible project activities and does not include natural or unmanaged soil carbon dynamics.</p>
SOC Removal	<p>An anthropogenic carbon removal achieved through a net increase in soil organic carbon stocks relative to a defined baseline scenario.</p> <p>SOC removals under this methodology are biological in nature and subject to potential reversibility.</p>
SOCBS	Soil organic carbon in the eligible project area before the project start.
SOM	Soil organic matter
SSM	Sustainable soil management
ST	Soil texture
t	Metric ton (or tonne)
TOC	Total organic carbon
Tot-N	Total nitrogen

1 Introduction

Soil organic carbon (SOC) plays a central role in the functioning, productivity, and resilience of agricultural and pastoral systems. Through its influence on soil structure, nutrient retention, water regulation, and biological activity, SOC underpins both agricultural sustainability and key ecosystem services.

Globally, soils constitute the largest terrestrial reservoir of organic carbon, containing more carbon than the atmosphere and terrestrial vegetation combined. As a result, changes in SOC stocks can have a material influence on the global carbon cycle and atmospheric CO₂ concentrations. These relationships are well established in the scientific literature and form the basis for the inclusion of soil carbon management within climate change mitigation strategies (Schlesinger, 1995; Jobbágy & Jackson, 2000; IPCC, 2019).

SOC stocks reflect a dynamic balance between carbon inputs, derived from plant residues, root systems, and organic amendments, and carbon losses driven by microbial decomposition, erosion, and other soil processes. Under stable land management conditions, SOC tends toward a dynamic equilibrium, while changes in land management practices can shift this balance, leading to either increases or decreases in SOC over time.

In agricultural landscapes, the application of organic amendments represents one pathway through which SOC stocks may be enhanced. Anaerobic digestion of organic waste streams produces digestate, a nutrient-rich residual material that can be applied to soils as part of sustainable land management practices. When appropriately treated and managed, digestate application may contribute to nutrient recycling and influence SOC dynamics, depending on the broader balance of carbon inputs, soil conditions, and management practices.

This methodology provides a structured framework to quantify anthropogenic increases in SOC stocks resulting from the application of digestates or effluents under managed agricultural systems. It adopts a conservative stock-change approach grounded in direct measurement, recognizes the inherently reversible nature of SOC, and applies robust safeguards related to additionality, permanence, uncertainty, leakage, and avoidance of double counting in accordance with the BioCarbon Standard.

By integrating established soil science with rigorous carbon accounting principles, this methodology aims to ensure that credited SOC removals represent real, additional, and verifiable climate mitigation outcomes.

2 Version and validity

This methodological document constitutes the Public Consultation Version 2.0 of the BCRO09 – Soil Organic Carbon (SOC) stock increase by adding high organic content from anaerobic digestate methodology.

This version is released for public consultation purposes only and does not enter into force until it is formally approved and published by BioCarbon Cert.

Following the public consultation process, BioCarbon Cert may revise this document to incorporate comments received from stakeholders. Only the final approved version, as published on the official BioCarbon Cert website, shall be considered valid for the registration of new projects under the BioCarbon Standard.

Until such approval and publication, project registration under this methodology shall not be permitted based on this consultation version.

3 Scope and applicability

This methodology applies exclusively to project activities that generate anthropogenic carbon removals through measurable and verifiable increases in soil organic carbon (SOC) stocks within managed lands under the AFOLU sector.

For the purposes of this methodology, SOC enhancements are treated as biological carbon removals subject to potential reversibility. Accordingly, all credited removals under this methodology are conditional upon continued maintenance of eligible land management practices and compliance with the permanence, monitoring, and risk management provisions of the BioCarbon Standard.

This methodology is applicable only to project activities that meet all of the following conditions:

- (a) The project activity implements additional land management practices that demonstrably increase SOC stocks relative to a clearly defined baseline scenario representing the continuation of pre-project land management practices;
- (b) The project activity is implemented on managed lands, including cropland, grassland, or other eligible AFOLU land categories, as defined by the BioCarbon Standard and consistent with applicable IPCC guidance;
- (c) The project activity does not include avoided emissions, fuel substitution, biomass production for energy purposes, or non-soil carbon pools;

- (d) The project activity applies approved quantification, monitoring, uncertainty management, permanence, leakage, and avoiding double counting tools adopted under the BioCarbon Standard, as applicable;
- (e) The project activity is not mandated by existing laws, regulations, or binding policies and demonstrates regulatory surplus in accordance with the BioCarbon Baseline and Additionality Tool.

This methodology does not apply to:

- (a) Activities that solely maintain existing SOC stocks without demonstrable incremental enhancement attributable to the project activity;
- (b) Activities where observed SOC changes cannot be distinguished from natural variability, climatic effects, or short-term management fluctuations;
- (c) Activities implemented on lands subject to unmanaged natural regeneration, unmanaged ecosystems, or land categories outside the AFOLU scope of the BioCarbon Standard;
- (d) Activities where SOC increases are already credited, claimed, or accounted for under another carbon crediting mechanism or national compliance framework.

SOC removals quantified under this methodology shall be credited only for the duration and magnitude for which net SOC stock increases are demonstrated, monitored, and maintained in accordance with this methodology and the BioCarbon Standard.

4 Eligibility

4.1 Project start date

The project start date is defined as the date on which the first application of digestate or effluent is implemented within the eligible project area, in accordance with this methodology.

The project start date shall occur after the establishment of the baseline scenario and prior to the commencement of any crediting or quantification period under the BioCarbon Standard.

Applications of digestate or effluent carried out prior to the defined project start date shall be considered part of the baseline scenario and shall not be eligible for crediting.

4.2 Geographic location

Project activities under this methodology may be implemented in any geographic region, subject to compliance with the eligibility conditions set out in this document and the BioCarbon Standard.

The geographic applicability of the project activity shall take into account site-specific conditions, including topography, soil characteristics, climate, and data availability, to ensure that changes in soil organic carbon (SOC) stocks can be reliably measured and verified.

Any geographic or environmental constraints that may limit the feasibility, effectiveness, or integrity of the project activity shall be identified and documented in the Project Document.

4.3 Project area

The project area shall comprise agricultural land used for annual crops, perennial crops, managed pasture, or fodder production, including fallow land, provided that such land meets all eligibility conditions of this methodology.

The project activity shall be implemented on the same land parcels used to define the baseline scenario. The spatial boundaries of the project area shall be clearly delineated, mapped, and documented in the Project Document.

Projects may be implemented at the scale of defined areas of intervention (DAI). Each DAI may include one or more fields within a single farm or across multiple farms, provided that land management practices, soil characteristics, and monitoring approaches are sufficiently homogeneous to allow reliable detection of changes in SOC stocks.

Where substantial differences in soil type, topography, land management practices, or other relevant characteristics exist within the project area, separate DAIs shall be defined to ensure conservative and accurate SOC quantification.

The project activity shall not be implemented on wetlands, peatlands, or forest land, nor on land that has undergone land use change within the period defined by the BioCarbon Standard.

Infrastructure areas within agricultural fields, including roads, irrigation infrastructure, or built structures, shall be excluded from the project area and from SOC quantification.

Land parcels requiring conversion from abandoned land through intensive tillage for agricultural use shall not be eligible under this methodology.

4.4 Site preparation

Site preparation activities within the project area shall be limited to practices that are consistent with sustainable land management and that do not result in a reduction of soil organic carbon (SOC) stocks relative to the baseline scenario.

The project activity shall not involve the burning of crop residues, stubble, or other biomass within the project area, as such practices would result in direct carbon losses and undermine SOC stock increases.

Any site preparation measures implemented prior to or at the project start date shall be documented in the Project Document and shall be consistent with the land management practices considered under the baseline scenario.

Site preparation activities shall not include intensive soil disturbance, land clearing, or other practices that would materially alter soil structure or carbon stocks in a manner inconsistent with the objectives of this methodology.

Where site preparation practices are necessary for agronomic or operational reasons, the project holder shall demonstrate that such practices do not result in net SOC losses and do not compromise the integrity of SOC quantification under this methodology.

4.5 Water regime

Project activities shall be implemented under water management conditions that are consistent with soil protection, environmental integrity, and the objectives of increasing soil organic carbon (SOC) stocks.

The project activity shall not introduce changes to surface or shallow subsurface water regimes that could reasonably result in increased greenhouse gas emissions, accelerated loss of SOC, or adverse impacts on soil or water quality.

The project holder shall demonstrate that the application of digestate or effluent:

- (a) Is compatible with existing irrigation or rainfall regimes and does not induce waterlogging, excessive runoff, or enhanced leaching of carbon or nutrients;
- (b) Is managed in a manner that minimizes the risk of nutrient losses to surface or groundwater, taking into account site-specific soil properties, climate conditions, and crop or pasture requirements;
- (c) Does not result in significant alterations of local hydrological conditions that could compromise the permanence of SOC stocks or lead to indirect environmental impacts.

Where irrigation is practiced, digestate or effluent application rates and timing shall be aligned with crop or pasture nutrient demand and water availability, in accordance with recognized good agricultural practice.

The project activity shall not involve the drainage of wetlands, peatlands, or other hydrologically sensitive areas, nor the conversion of such areas for the purpose of implementing the project.

4.6 Land use

Project activities shall be implemented on land that is demonstrably used for agricultural or pastoral purposes prior to the project start date.

The project holder shall demonstrate that the project area has been under continuous agricultural land use, including cropland, permanent crops, or managed pasture, for a minimum period prior to the project start date, in accordance with the BioCarbon Standard.

The project activity shall not result in land use change, including but not limited to:

- (a) Conversion of forest land, wetlands, peatlands, or other natural ecosystems to agricultural land;
- (b) Conversion of pasture to cropland or other land uses that could reasonably lead to increased greenhouse gas emissions or loss of soil organic carbon (SOC);
- (c) Reclamation of abandoned or degraded lands where the primary SOC increase would be attributable to land conversion rather than to the project activity.

The project holder shall demonstrate that the project activity is implemented within the same land parcels used for the establishment of the baseline scenario and that any changes in land management practices do not constitute a land use change.

Land use conditions shall be monitored and documented throughout the quantification period to ensure continued compliance with these requirements.

4.7 Food security

Project activities shall not result in adverse impacts on food security attributable to the implementation of the project.

The project holder shall demonstrate that crop or pasture productivity within the project area is maintained at levels comparable to the baseline scenario, taking into account normal inter-annual variability and regional production trends.

During the quantification period, the project activity shall not cause a systematic reduction in yields that exceeds reasonable variability when compared to baseline conditions or regional reference values.

Where changes in crop type, rotation, or management practices occur as part of the project activity, the project holder shall demonstrate that such changes do not negatively affect overall food production or availability attributable to the project.

Food security considerations shall be documented in the Project Document (PD) and subject to validation and verification in accordance with the BioCarbon Standard.

4.8 Digestate or effluent characteristics and quality

The use of digestate or effluent under this methodology shall be subject to conditions that ensure its suitability for land application and its consistency with environmental protection, soil health, and climate mitigation objectives.

Digestate or effluent applied under the project activity shall originate from an anaerobic digestion process and shall demonstrate an adequate level of organic matter stabilization and hygienization, in accordance with applicable regulatory requirements and recognized good practice.

The project holder shall demonstrate, through documented evidence, that the digestate or effluent used:

- (a) Does not cause phytotoxic effects or adverse impacts on soil physical, chemical, or biological properties;
- (b) Does not result in excessive concentrations of readily degradable compounds, volatile substances, or other constituents that could negatively affect soil quality or ecosystem functioning;
- (c) Is applied at rates consistent with crop or pasture nutrient requirements and soil conditions, taking into account existing nutrient inputs and site-specific agronomic constraints.

The chemical composition and physical characteristics of digestate or effluent, including nutrient content and potential contaminants, shall be documented and made available for validation and verification.

Digestate or effluent quality shall be assessed in relation to applicable health, environmental, and agricultural regulations governing the use of organic amendments, including, where relevant, regulations concerning animal by-products and derived products not intended for human consumption.

Where digestate or effluent originates from an anaerobic digestion facility that is registered or certified under another carbon crediting program or climate mitigation scheme, the project holder shall transparently disclose this information and demonstrate that emissions associated with digestate or effluent use are not already accounted for under another methodology or program.

This methodology does not prescribe specific engineering configurations, operational parameters, or digestion technologies. Instead, it requires the project holder to demonstrate that the digestate or effluent applied under the project activity meets the environmental integrity, soil protection, and monitoring requirements set out in this methodology and the BioCarbon Standard.

5 Baseline and Additionality

5.1 Baseline scenario

The baseline scenario under this methodology represents the continuation of pre-project land management practices and associated soil organic carbon (SOC) stock dynamics that would

reasonably be expected to occur in the absence of the project activity and carbon crediting incentives.

The baseline SOC scenario shall be established based on historical and current land management practices implemented on the project area prior to the project start date. Improvements in land management practices introduced as part of the project activity shall not be included in the baseline scenario.

Baseline SOC dynamics shall be defined in a conservative and static manner, such that:

- (a) The baseline reflects SOC stock changes attributable to the continuation of pre-project practices only;
- (b) Short-term SOC fluctuations resulting from climatic variability, inter-annual weather patterns, or natural soil processes shall not be credited as baseline improvements;
- (c) Anticipated future adoption of improved practices, policy trends, market signals, or incentive schemes shall not be incorporated into the baseline scenario.

The selection and justification of the baseline scenario shall be consistent with IPCC guidance for AFOLU activities, applying a hierarchical approach to methodological rigor, whereby:

- (a) Higher-tier methods (Tier 2 or Tier 3) shall be used where data availability and project circumstances allow;
- (b) Where lower-tier methods (Tier 1) are applied, conservative default assumptions shall be used;
- (c) In all cases, the most conservative plausible baseline shall prevail where methodological choices exist.

The baseline SOC scenario shall remain fixed for the duration of each monitoring period, unless a baseline reassessment is explicitly required under the BioCarbon Standard. Any such reassessment shall not result in an increase of credited SOC removals.

Baseline SOC estimates shall be established in a manner that avoids overlap or double counting with national greenhouse gas inventories and shall be consistent with the principles set out in the BioCarbon Avoiding Double Counting Tool.

5.2 Demonstration of additionality

Project activities applying this methodology shall demonstrate additionality in accordance with the BioCarbon Baseline and Additionality Tool, as applicable to AFOLU activities and soil organic carbon (SOC) removals.

SOC removals shall not be presumed additional by virtue of their environmental benefits or alignment with sustainable land management objectives. Additionality shall be demonstrated by establishing that the implementation of the project activity and the resulting SOC increases would not have occurred in the absence of carbon crediting incentives.

The demonstration of additionality shall include, at a minimum, the following elements:

(a) Regulatory Surplus

The project activity shall not be mandated by existing laws, regulations, policies, or legally binding requirements at the national, subnational, or sectoral level.

SOC increases resulting from compliance with mandatory agricultural, environmental, or climate-related regulations shall not be considered additional.

(b) Common Practice Assessment

The project activity shall not constitute common practice within the relevant geographic, climatic, and management context at the time of project start.

SOC-enhancing practices that are widely adopted, routinely implemented, or promoted as standard practice—regardless of their mitigation benefits—shall not be considered additional unless the project proponent demonstrates that such practices face clearly identifiable barriers that are overcome through carbon crediting.

(c) Investment, Financial, or Implementation Barriers

The project proponent shall demonstrate the presence of financial, institutional, technical, or behavioral barriers that would prevent the adoption or sustained implementation of the project activity in the absence of carbon finance.

The removal of such barriers through carbon credit revenues shall be clearly documented.

(d) Exclusion of Incentive-Driven Non-Additional Activities

SOC increases resulting from public subsidies, incentive programs, or results-based payments that are explicitly designed to promote the same land management practices shall not be credited unless appropriate adjustments are applied in accordance with the BioCarbon Avoiding Double Counting Tool.

Additionality shall be assessed ex ante at the time of project validation and shall be reassessed where required under the BioCarbon Standard. Failure to maintain the conditions supporting additionality may result in the suspension or adjustment of credited SOC removals.

6 Permanence and reversal risk management

Soil organic carbon (SOC) removals quantified under this methodology are biological in nature and inherently subject to potential reversibility. Accordingly, all credited SOC removals shall be subject to permanence and reversal risk management provisions designed to ensure the long-term environmental integrity of issued credits under the BioCarbon Standard.

6.1 Recognition of reversibility

SOC stocks may decrease as a result of changes in land management practices, natural disturbances, climatic events, or other anthropogenic or non-anthropogenic factors. This methodology explicitly recognizes that SOC removals are not permanent by default and require ongoing management, monitoring, and risk mitigation throughout the quantification period and any applicable post-quantification monitoring period.

6.2 Reversal risk assessment

Each project activity applying this methodology shall conduct a reversal risk assessment in accordance with the BioCarbon Permanence and Reversal Risk Tool.

The reversal risk assessment shall identify, evaluate, and document all relevant risks that could reasonably result in a decrease of credited SOC stocks, including but not limited to:

- (a) Changes in land tenure, ownership, or land management practices;
- (b) Environmental, climatic, or biophysical disturbances;
- (c) Economic, institutional, or governance-related risks;
- (d) Any other factor that could materially affect the maintenance of SOC stocks over time.

The assessment shall be conducted ex ante and updated where required by the BioCarbon Standard.

6.3 Risk mitigation and reversal compensation measures

Based on the outcome of the reversal risk assessment, project activities shall apply the risk mitigation and reversal compensation measures specified in the BioCarbon Permanence and Reversal Risk Tool.

Such measures may include, where applicable, the withholding, retention, or cancellation of credits, or other mechanisms defined by the BioCarbon Standard, to ensure that any identified or realized reversals are fully and conservatively addressed.

Credits subject to risk mitigation measures shall not be issued, transferred, or claimed until all applicable permanence requirements have been satisfied.

6.4 Monitoring and maintenance obligations

Project activities shall maintain eligible land management practices throughout the quantification period and any applicable post-quantification monitoring period, in accordance with this methodology and the BioCarbon Standard.

SOC stocks shall be monitored at regular intervals as defined in the monitoring requirements. Any material deviation from expected SOC levels shall be investigated, documented, and assessed for potential reversals.

6.5 Reversal identification and management

A reversal shall be deemed to have occurred where monitored SOC stocks fall below previously credited levels, irrespective of cause.

Where a reversal is identified:

- (a) The magnitude of the reversal shall be quantified using conservative assumptions;
- (b) An equivalent quantity of credits shall be cancelled or otherwise compensated through the applicable risk mitigation measures defined by the BioCarbon Standard;
- (c) Corrective actions shall be implemented where feasible to prevent further reversals.

Intentional and unintentional reversals shall be addressed in accordance with the BioCarbon Permanence and Reversal Risk Tool and associated procedures.

6.6 Interaction with quantification and monitoring periods

SOC removals shall be credited only for the duration and magnitude for which SOC stock increases are demonstrably maintained in accordance with this methodology.

Failure to maintain SOC stocks or comply with permanence requirements may result in the suspension, adjustment, or cancellation of credited SOC removals, without prejudice to additional measures required under the BioCarbon Standard.

6.7 Precedence of the Permanence Tool

In the event of any inconsistency between this methodology and the BioCarbon Permanence and Reversal Risk Tool, the provisions of the BioCarbon Permanence and Reversal Risk Tool shall prevail.

7 Leakage identification and management

Soil organic carbon (SOC) project activities may give rise to leakage risks where the implementation of SOC-enhancing land management practices results in an increase in greenhouse gas emissions or a decrease in carbon stocks outside the project boundary.

Accordingly, potential leakage shall be systematically identified, assessed, and conservatively addressed.

7.1 Leakage identification

Each project activity applying this methodology shall conduct a leakage identification and screening assessment to determine whether the implementation of the project activity could reasonably cause displacement of activities, land management practices, or production that leads to increased emissions or reduced carbon stocks outside the project boundary.

Potential sources of leakage may include, but are not limited to:

- (a) Displacement of land management practices, where SOC-enhancing practices within the project boundary result in the relocation of less sustainable practices to other areas;
- (b) Activity shifting, where agricultural or land-use activities displaced by the project are transferred to other lands outside the project boundary;
- (c) Market-mediated effects, where changes in production or land use associated with the project activity indirectly incentivize increased emissions elsewhere.

7.2 Leakage screening and applicability

Leakage shall be considered negligible where the project activity does not involve:

- (a) Expansion of production capacity beyond pre-project levels;
- (b) Displacement of agricultural or land-use activities to areas outside the project boundary;
- (c) Conversion of land uses that would reasonably lead to increased emissions elsewhere.

Where leakage risks are identified as potentially material, the project proponent shall provide a conservative qualitative or quantitative justification demonstrating that such leakage is either negligible or adequately addressed.

Leakage shall be considered negligible where the project activity does not involve the conditions listed above, unless demonstrated otherwise through conservative assessment.

7.3 Conservative treatment of leakage

In cases where potential leakage cannot be robustly excluded, the project activity shall apply conservative assumptions to ensure that credited SOC removals are not overestimated.

Leakage deductions, where applicable, shall be quantified using conservative approaches consistent with IPCC guidance and the BioCarbon Standard. Where quantitative estimation is not feasible, conservative exclusion of affected SOC removals shall be applied.

7.4 Exclusion of Indirect Land-Use Change (iLUC) quantification

This methodology does not require explicit modeling or quantification of indirect land-use change (iLUC).

However, project activities that could reasonably result in indirect displacement effects shall demonstrate, through conservative screening, that such effects are unlikely to materially affect the integrity of credited SOC removals.

7.5 Documentation and Verification

All leakage identification, screening, assumptions, and mitigation measures shall be transparently documented in the PD and shall be subject to validation and verification in accordance with the BioCarbon Standard.

Failure to adequately address identified leakage risks may result in conservative adjustment or exclusion of credited SOC removals.

8 Uncertainty assessment and conservative adjustment

Uncertainty is an inherent characteristic of soil organic carbon (SOC) quantification due to spatial variability, temporal dynamics, sampling limitations, and measurement error. Accordingly, all SOC removals quantified under this methodology shall be subject to a systematic uncertainty assessment and conservative adjustment to ensure environmental integrity and avoid overestimation of credited removals.

8.1 Identification of Uncertainty Sources

Each project activity applying this methodology shall identify and document all relevant sources of uncertainty associated with the quantification of SOC removals, including but not limited to:

- (a) Soil sampling design and representativeness;
- (b) Measurement and laboratory analysis error;
- (c) Spatial heterogeneity of SOC stocks;
- (d) Temporal variability and monitoring frequency;
- (e) Modeling assumptions and parameter uncertainty, where applicable.

8.2 Application of the BioCarbon Uncertainty Tool

The quantification of SOC removals shall be subject to an uncertainty assessment conducted in accordance with the BioCarbon Uncertainty Assessment Tool, as applicable to AFOLU activities.

The project proponent shall apply the procedures, confidence level requirements, and conservative adjustment rules defined in the BioCarbon Uncertainty Assessment Tool to determine whether uncertainty exceeds acceptable thresholds.

8.3 Conservative adjustment of SOC Removals

Where uncertainty exceeds the confidence level required by the BioCarbon Standard, a conservative adjustment shall be applied to quantified SOC removals prior to credit issuance.

Conservative adjustments may include, as applicable:

- (a) Discounting of quantified SOC removals;
- (b) Exclusion of uncertain SOC stock changes;
- (c) Application of conservative default values or parameters.

SOC removals shall not be credited where uncertainty cannot be adequately characterized or conservatively addressed.

8.4 Interaction with monitoring and permanence

Uncertainty assessments shall be conducted *ex ante* at validation and updated as required during subsequent monitoring and verification events throughout the quantification period.

Where uncertainty contributes to ambiguity regarding the maintenance of credited SOC stocks, such uncertainty shall be addressed in a manner consistent with the permanence and reversal risk management provisions of this methodology and the BioCarbon Standard.

8.5 Documentation and verification

All uncertainty assessments, assumptions, calculations, and conservative adjustments shall be transparently documented in the PD and Monitoring Reports and shall be subject to validation and verification in accordance with the BioCarbon Standard.

8.6 Precedence of the Uncertainty Tool

In the event of any inconsistency between this methodology and the BioCarbon Uncertainty Assessment Tool, the provisions of the BioCarbon Uncertainty Assessment Tool shall prevail.

9 Quantification of Soil Organic Carbon removals

9.1 Quantification approach

Soil organic carbon (SOC) removals under this methodology shall be quantified using a stock-change approach based on direct measurement of SOC stocks over time.

SOC stocks and SOC stock changes shall be quantified using the equations set out in this section. These equations constitute the mandatory methodological basis for the calculation of SOC stocks and SOC stock changes under this methodology.

The results obtained from the application of these equations represent gross SOC stock changes. The amount of SOC removals eligible for crediting shall be determined only after the application of all applicable baseline, additionality, uncertainty, permanence, leakage, and avoiding double counting provisions set out in this methodology and the BioCarbon Standard.

9.2 Stratification and baseline SOC estimation

For each eligible project area, the project holder shall establish baseline SOC stocks prior to the start of project activities, in accordance with the baseline methodology defined in this document.

The project area shall be stratified into homogeneous land units based on soil type, land use, management history, and other relevant characteristics. SOC stocks shall be quantified separately for each stratum.

Baseline SOC stocks shall reflect the continuation of pre-project land management practices and shall not include any effects attributable to the project activity.

9.3 Soil sampling design

SOC stocks shall be determined using a statistically representative composite sampling design within each homogeneous unit.

Composite samples shall consist of multiple subsamples distributed across the unit to capture spatial variability. Sampling designs shall be documented and implemented consistently across all measurement periods.

9.3.1 Sampling Depth

Unless otherwise justified and conservatively assessed:

- For annual and seasonal crops and pastures, soil sampling shall be conducted at 0–0.30 m depth;
- For permanent crops, orchards, and vineyards, soil sampling shall be conducted at 0–0.30 m and 0.30–0.60 m depths.

Any deviation from these depths shall be technically justified and subject to uncertainty assessment.

9.4 Laboratory analysis and soil parameters

SOC content and supporting soil parameters shall be determined using internationally recognized and scientifically accepted methods, including applicable ISO standards.

At a minimum, laboratory analysis shall include:

- Soil organic carbon or total carbon content;
- Soil bulk density;
- Soil texture and pH, where relevant for stratification and uncertainty assessment.

Analytical methods shall be applied consistently across all quantification periods.

9.5 Soil Bulk Density Determination

Soil bulk density (D_b) shall be determined for each depth increment using undisturbed soil cores.

Bulk density shall be calculated as:

$$D_b = \frac{M_s}{V_t} \quad \text{Equation (1)}$$

Where:

- D_b = Soil bulk density (g cm^{-3})
- M_s = Oven-dried soil mass (g)
- V_t = Total volume of the soil core (cm^3)

Where coarse roots or mineral fragments greater than 2 mm are present, bulk density shall be corrected as follows:

$$D_b = \frac{M_s}{V_t - \left(\frac{RF}{PD}\right)} \quad \text{Equation (2)}$$

Where:

- RF = Mass of coarse fragments (g)
- PD = Particle density of coarse fragments (default value of 2.65 g cm^{-3} may be used unless site-specific data are available)

Bulk density shall be determined separately for each depth increment.

9.6 Calculation of SOC stocks

SOC stocks shall be calculated for each stratum and depth increment as follows:

$$SOC_{stock,pj} = 100 \times (D_b \times D \times \%C) \quad \text{Equation (3)}$$

Where:

$SOC_{stock,pj}$	=	Soil organic carbon stock (t C ha ⁻¹) in period j
D_b	=	Soil bulk density (g cm ⁻³)
D	=	Thickness of the sampled soil layer (cm)
$\%C$	=	Soil carbon content (%)

SOC stocks shall be aggregated across depth increments and strata to determine total SOC stocks for the project area.

9.7 Quantification of SOC Stock Changes

Net SOC stock changes shall be quantified as the difference between SOC stocks measured in consecutive quantification periods, as follows:

$$\Delta SOC = SOC_{stock,p2} - SOC_{stock,p1} \quad \text{Equation (4)}$$

Where:

ΔSOC	=	Change in SOC stocks (t C ha ⁻¹)
$SOC_{stock,p2}$	=	SOC stock in the current quantification period
$SOC_{stock,p1}$	=	SOC stock in the previous quantification period

SOC stock changes shall be quantified separately for each quantification period and shall not be extrapolated beyond measured periods.

Where SOC stock changes are not statistically distinguishable from zero after application of uncertainty and conservative adjustments, no SOC removals shall be credited for the relevant quantification period.

9.8 Use of SOC Models

SOC simulation models (e.g. RothC or IPCC Tier 2 steady-state approaches) may be used only as supporting tools for stratification, baseline characterization, or consistency checks.

SOC models shall not replace direct measurement of SOC stocks for credit quantification. Any model-based inputs shall be conservatively applied and subject to the uncertainty assessment provisions of this methodology.

9.9 Treatment of Non-CO₂ Emissions

Where relevant, non-CO₂ emissions associated with project activities (e.g. N₂O or NH₃ emissions related to organic amendments) shall be addressed separately and conservatively, in accordance with applicable sections of this methodology and the BioCarbon Standard.

10 Avoiding double counting and interaction with national accounting

Soil organic carbon (SOC) removals quantified under this methodology shall be subject to robust safeguards to prevent double counting, double claiming, or double use of greenhouse gas mitigation outcomes.

10.1 General Principle

SOC removals credited under this methodology shall represent unique, exclusive, and verifiable mitigation outcomes that are not simultaneously claimed, credited, or used under any other carbon crediting mechanism, compliance scheme, or national greenhouse gas accounting framework, unless explicitly permitted and adjusted in accordance with the BioCarbon Standard.

10.2 Interaction with national Greenhouse Gas Inventories

SOC stock changes occurring within the project boundary may be reflected in national greenhouse gas inventories prepared under the AFOLU sector.

The crediting of SOC removals under this methodology does not imply ownership or control over national inventory accounting. Project proponents shall ensure that credited SOC removals are managed in a manner consistent with the principles of transparency, environmental integrity, and avoidance of double claiming, as set out in the BioCarbon Standard.

Where relevant, project activities shall apply the procedures defined in the BioCarbon Avoiding Double Counting Tool to assess and address potential overlaps between project-level crediting and national accounting.

10.3 Interaction with Policies, Incentives, and Other Programs

SOC removals resulting from activities that are:

- (a) Required by law or regulation;
- (b) Fully funded or mandated by public policies or incentive schemes; or

(c) Credited under another carbon market or results-based payment mechanism, shall not be credited under this methodology unless appropriate adjustments are applied in accordance with the BioCarbon Avoiding Double Counting Tool.

10.4 Exclusive claiming of credits

Credits issued for SOC removals under this methodology shall be claimed exclusively by the entity entitled under the BioCarbon Standard and shall not be used to substantiate overlapping mitigation claims by other entities, programs, or jurisdictions.

10.5 Documentation and Verification

All assessments, assumptions, and determinations related to avoiding double counting shall be transparently documented in the PD and shall be subject to validation and verification in accordance with the BioCarbon Standard.

10.6 Precedence of the Avoiding Double Counting Tool

In the event of any inconsistency between this methodology and the BioCarbon Avoiding Double Counting Tool, the provisions of the BioCarbon Avoiding Double Counting Tool shall prevail.

11 Monitoring requirements

Monitoring under this methodology shall ensure the accurate, transparent, consistent, and conservative quantification of soil organic carbon (SOC) removals throughout the applicable quantification period, in accordance with the BioCarbon Standard.

11.1 Monitoring objectives

The objectives of monitoring are to:

- (a) Quantify changes in SOC stocks attributable to the project activity;
- (b) Detect potential reversals or deviations from expected SOC trajectories;
- (c) Support the application of uncertainty assessment, permanence, and leakage provisions;
- (d) Provide verifiable evidence for validation and verification.

11.2 Monitoring Plan

Each project activity shall develop and implement a Monitoring Plan prior to the start of the first quantification period.

The Monitoring Plan shall describe, at a minimum:

- (a) Soil sampling design and stratification;
- (b) Sampling frequency and timing;
- (c) Measurement and laboratory analysis methods;
- (d) Data management, quality assurance, and quality control procedures;
- (e) Procedures for addressing missing or incomplete data;
- (f) Responsibilities for data collection, storage, and reporting.

The Monitoring Plan shall be consistent with IPCC guidance for AFOLU activities and the BioCarbon Standard.

Further operational guidance on monitoring parameters, data management, and measurement procedures is provided in Appendix 1 (Indicative monitoring parameters and data requirements), which complements and supports the monitoring requirements set out in this section.

11.3 Sampling design and frequency

SOC shall be monitored using a statistically representative sampling design appropriate to the spatial heterogeneity of soils within the project boundary.

Sampling shall be conducted:

- (a) At project initiation to establish baseline SOC conditions;
- (b) At regular intervals during the quantification period, as defined in the Monitoring Plan;
- (c) Following any event or circumstance that could reasonably result in a reversal.

Where higher sampling frequency or intensity is required to address uncertainty or heterogeneity, conservative assumptions shall be applied.

11.4 Measurement and analytical methods

SOC measurements shall be conducted using recognized and scientifically accepted methods, including appropriate laboratory analysis techniques.

Measurement methods shall be applied consistently across monitoring events. Any changes in methods shall be justified, documented, and conservatively reconciled to ensure comparability over time.

11.5 Treatment of missing or incomplete data

Where monitoring data are missing, incomplete, or invalid, the project activity shall apply conservative assumptions to avoid overestimation of SOC removals.

SOC removals shall not be credited for periods or areas where reliable monitoring data are unavailable or insufficient to meet the confidence requirements of the BioCarbon Standard.

11.6 Data management and record keeping

All monitoring data, including raw data, laboratory results, calculations, and supporting documentation, shall be retained in accordance with the BioCarbon Standard and made available for validation and verification.

Data shall be stored in a manner that ensures integrity, traceability, and protection against unauthorized modification.

11.7 Verification and quality control

Monitoring results shall be subject to independent validation and verification in accordance with the BioCarbon Standard.

Project activities shall implement quality assurance and quality control (QA/QC) procedures to ensure the accuracy and consistency of monitoring data.

Any discrepancies identified during verification shall be addressed through corrective actions or conservative adjustments, as applicable.

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Document History

Version	Date	Description
Version 1.0	November 4, 2024	Initial version of the methodological document
Version 2.0	February 9, 2026	Public consultation version, incorporating substantial methodological revisions, structural reorganization, and alignment with the BioCarbon Standard, ICVCM Core Carbon Principles, and best practices for soil organic carbon accounting.

Minor editorial or formatting updates that do not affect methodological requirements may be made without incrementing the version number.

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Appendix 1. Indicative monitoring parameters and data requirements

The Monitoring Plan shall describe the operational procedures for the collection, management, and archiving of data required to implement the monitoring requirements set out in this methodology and the BioCarbon Standard.

The Monitoring Plan shall provide for the collection of all relevant data necessary to:

- a) Verify that all applicability conditions of the methodology continue to be met throughout the applicable quantification period;
- b) Quantify and verify changes in soil organic carbon stocks within the defined project boundary;
- c) Quantify and verify project emissions, potential leakages, and any other relevant sources of uncertainty, as applicable.

Data Management and Archiving

All data collected under the Monitoring Plan shall be accurately recorded, securely stored, and archived for a minimum period consistent with the BioCarbon Standard following the end of the project's last quantification period.

Archived information shall include, at a minimum:

- a) Data and parameters monitored and reported;
- b) Models, methods, and assumptions used to generate or process monitoring data;
- c) Sampling design, sampling procedures, laboratory analyses, and quality assurance/quality control (QA/QC) measures;
- d) Documentation supporting conservative assumptions, uncertainty treatment, and data gap management;
- e) Validation and verification reports, statements, and opinions issued throughout the project lifecycle.

Scope of Monitoring Activities

The Monitoring Plan shall include procedures for:

- a) Monitoring the project boundary, including any relevant changes affecting eligibility, permanence, or leakage risks;

b) Monitoring the implementation and maintenance of project activities, including land management practices and any application of organic amendments, where applicable, that may influence SOC dynamics.

Indicative Monitoring Parameters

The table below provides an indicative and non-exhaustive summary of monitoring parameters relevant to projects applying this methodology.

The selection, frequency, and level of detail of monitored parameters shall be consistent with the monitoring requirements of this methodology, the BioCarbon Standard, and the project-specific Monitoring Plan.

Table 1. Indicative monitoring parameters for SOC projects

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
Digestate COD	Mg/L	m	Yearly	Measure the COD according to national or international standards. COD is measured through representative sampling	Samples and measurements shall ensure a 90/10 confidence/precision level
Location	Geographic coordinates	m	Continuously	100%	Using GPS to identify the geographic coordinates of each plot included in the project
Project Area	hectare	c	Continuously	100%	Polygons of the areas include in the project

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
Defined Area of intervention (DAI)	hectare	c	Continuously	100% of the intervened	Polygons of the areas where the digestate is applied.
Date of digestate application	alphanumeric	m	Dates when digestate is applied to soil	100%	Dates can include ranges of consecutive or no consecutive days
Type(s) of crop(s)	dimensionless	m	Continuously	100%	Description current crops and changes over the time e.g. from single cropping to rotational crop.
Annual average crop yield	Tonnes/ha	m	Continuously	100%	The crop productivity shall be crosschecked with average regional yields for the specific crop(s).
Amount of fertilizers, pesticides, additives used	Kg/ha	m	Continuously	100%	Invoices and application records can be used to report this parameter.
Change in hydrology	dimensionless	e	Annual	100%	Annual report of changes in irrigation patterns, drainage and

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
					crop/pasture cover.
Change in the technical management of the crop	dimensionless	e	Annual	100%	Annual report of changes in machinery used for sowing, cultivation and harvesting.
Change in the technical activities	dimensionless	e	Annual	100%	Annual report of changes in harvest, fallow period, mulch season.
Retention time of digestate at anaerobic reactor	days	m, c	Monthly	100%	Operation information of the reactor can be used as source for this parameter. Alternatively, the retention time can be estimated based on volume capacity of the reactor and amount of inflow volume.
Tillage practices	dimensionless	m	Annual	100%	Report of the tillage system, number and type of tillage operations per year, including all annual

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
					mechanized agricultural operations
Fossil fuel consumption	liters	m, c	Monthly	100%	Fossil fuel consumed in vehicles and pumps used to transport and application of the digestate.
Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
Soil bulk density (D _b)	g/cm ³	c	Every carbon stock campaign	Representative sampling	Sampling should meet 90/10 confidence interval and precision level.
<i>Depth of the sample</i>	cm	m	Every sample taken	100% of the samples	When required, depth increments should be recorded as well.
<i>Diameter of the sample</i>	cm	m	Every sample taken	100% of the samples	It is based on the diameter of the auger used for taking the samples.

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
Volume of the soil samples	cm ³	c	Every sample taken	100% of the samples	The volume is based on the sampling soil core extracted and calculated based on the dimension of the auger or soil probe used, diameter and depth of the sample.
Corrected Soil bulk density. D _b	g/cm ³	c	Every carbon stock campaign	Representative sampling	Sampling should meet 90/10 confidence interval and precision level. ¹ The corrected (D _b) is required when pre coarse roots and mineral fragments >2mm.
Mass of coarse root and fragments RF	grams	m	Every sample taken	100% of the samples (if applicable)	Applicable when presence of coarse root and fragments.

¹ For guidance on statistical measure and uncertainty assessment, please observe the guidance provided in the box 3.3 from the World Bank. (2021). Soil Organic Carbon MRV Sourcebook for Agricultural Landscapes.

Parameter	Unit	Measure (m), Calculate (c), estimated (e), or Default (d)	Monitoring frequency	Coverage, kind of measurement	Comments
Density of rocks fragments PF	g/cm ³	e	Every sample taken	100% of the samples (if applicable)	A default of 2.65 g cm ⁻³ can be Assumed. Applicable when presence of coarse root and fragments.
Soil carbon stocks, in period, j	t/ha	c	Representative samples	Calculated for each area strata.	Calculated for a given period (j), and recalculated in later periods to determine carbon gains or losses.

Technical Reference for Soil Sampling and Measurement

For field soil sampling, laboratory analysis, and the design of soil carbon measurement plans, project proponents may apply internationally recognized technical guidance consistent with IPCC good practice.

In particular, the procedures and recommendations described in Module A: Field Measurement of Soil Carbon, including:

- Part A: Field methods to assess soil carbon;
- Part B: Laboratory methods to assess soil carbon; and
- Part C: How to design a soil carbon measurement plan,

as set out in the World Bank (2021). Soil Organic Carbon MRV Sourcebook for Agricultural Landscapes may be used as an acceptable technical reference, provided that their application is consistent with this methodology and the BioCarbon Standard.

The use of alternative scientifically robust and internationally recognized methodologies shall be permitted, subject to validation and verification.

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Appendix 2. Scientific basis for the Soil Organic Carbon quantification

2.1 Purpose and Scope of this Appendix

This appendix provides the scientific basis underpinning the methodological choices set out in this document. It summarizes established scientific understanding related to soil organic carbon (SOC) dynamics, land management practices, anaerobic digestate characteristics, and measurement approaches relevant to SOC quantification.

The content of this appendix is explanatory in nature and is intended to support transparency, scientific credibility, and technical understanding. It does not introduce additional eligibility criteria, methodological requirements, or crediting rules beyond those defined in the main body of the methodology.

In the event of any inconsistency between this appendix and the normative provisions of the methodology or the BioCarbon Standard, the provisions of the methodology and the BioCarbon Standard shall prevail.

2.2 Soil Organic Carbon in Agroecosystems

Soil organic carbon (SOC) is a fundamental component of soil organic matter and plays a central role in the functioning, productivity, and resilience of agroecosystems. Through its influence on soil structure, nutrient retention, water regulation, and biological activity, SOC supports key ecosystem services and underpins agricultural sustainability (Ontl & Schulte, 2012).

At the global scale, soils represent the largest terrestrial reservoir of organic carbon, containing more carbon than the atmosphere and terrestrial vegetation combined (Schlesinger, 1995; Jobbágy & Jackson, 2000). As a result, changes in SOC stocks, even at relatively small magnitudes, can have material implications for the global carbon cycle and atmospheric CO₂ concentrations.

Within agricultural landscapes, SOC stocks are shaped by land use history, soil properties, climate, and management practices. While SOC typically represents a small fraction of total soil mass, its influence on soil function is disproportionate, making it a key variable for both agronomic performance and climate change mitigation (Bar-On et al., 2018).

2.3 Soil Carbon Inputs, Outputs, and Dynamic Equilibrium

Soil organic carbon (SOC) stocks in agricultural systems are governed by the balance between carbon inputs to the soil and carbon losses through biological and physical processes (Paustian et al., 1997; Lal et al., 1998). This balance determines whether SOC stocks increase, remain stable, or decline over time.

Carbon inputs to soil originate primarily from plant-derived sources, including aboveground crop residues, root biomass, rhizodeposition, and organic amendments applied to the soil surface or incorporated into the soil profile (Henderson, 1995; Paustian et al., 1997). In managed agroecosystems, additional carbon inputs may derive from externally sourced organic materials, such as manures, digestates, composts, and other high-organic-content amendments (Lal et al., 1998).

Carbon losses from soil occur mainly through microbial decomposition of soil organic matter, resulting in the release of carbon dioxide to the atmosphere, with additional pathways including physical removal through erosion and leaching of dissolved organic carbon (Entry & Emmingham, 1998; Wang et al., 1999). The relative importance of these loss pathways varies with soil type, climate, topography, and management practices (Jobbágy & Jackson, 2000; Wang et al., 1999).

Under stable land management conditions, SOC stocks tend toward a dynamic equilibrium in which long-term average carbon inputs are approximately balanced by carbon losses (Paustian et al., 1997). This equilibrium is not static, but reflects continuous turnover of organic matter within the soil. Changes in land management practices, organic input quantity or quality, or environmental conditions can shift this balance, leading to gradual increases or decreases in SOC stocks over time (Lal et al., 1998; IPCC, 2019).

Importantly, SOC increases are not unlimited. As soils accumulate organic carbon, the marginal efficiency of additional carbon inputs may decline due to constraints such as saturation of stabilization mechanisms and changes in decomposition dynamics (IPCC, 2019). Consequently, SOC dynamics are best understood as a gradual adjustment toward a new equilibrium rather than as linear or indefinite carbon accumulation (Paustian et al., 1997; IPCC, 2019).

These principles underpin the conservative design of the stock-change approach adopted in this methodology, which focuses on measured changes in SOC stocks over defined quantification periods and avoids assumptions of permanent or unlimited soil carbon sequestration (IPCC, 2019).

2.4 Conceptual SOC pools and stabilization mechanisms

Soil organic carbon (SOC) is commonly described using conceptual frameworks that distinguish organic matter fractions according to their relative turnover rates and degrees of stabilization (von Lützow et al., 2008; Torn et al., 2009). These frameworks do not represent discrete or fixed compartments, but rather a continuum of organic matter transformation processes occurring within the soil (von Lützow et al., 2008).

More rapidly cycling SOC fractions are associated with recent organic inputs derived from plant residues, root biomass, microbial biomass, and other readily decomposable materials (Torn et al., 2009). These fractions respond quickly to changes in organic inputs and land management practices and are therefore sensitive indicators of short- to medium-term management effects.

SOC fractions with intermediate turnover rates arise from the progressive transformation of more labile organic matter and remain biologically active, making them responsive to soil disturbance, residue management, and other agronomic practices that affect microbial activity and soil structure (von Lützow et al., 2008; Torn et al., 2009).

More stabilized SOC fractions persist over substantially longer timescales and contribute to long-term carbon storage in soils (Torn et al., 2009). Stabilization is not solely a function of the chemical recalcitrance of organic compounds, but is strongly influenced by physical and chemical protection mechanisms within the soil matrix (von Lützow et al., 2008; Dignac et al., 2017). These mechanisms include the incorporation of organic matter within soil aggregates and the association of organic compounds with mineral surfaces, which reduce accessibility to decomposer organisms (Dignac et al., 2017).

The relative contribution of these stabilization mechanisms varies with soil texture, mineralogy, climate, and management history (von Lützow et al., 2008; Dignac et al., 2017). As a result, the capacity of soils to retain additional organic carbon differs across sites and is subject to environmental and management constraints (IPCC, 2019).

This conceptual understanding of SOC pools and stabilization mechanisms supports the recognition that soil carbon sequestration is inherently reversible and context-dependent (IPCC, 2019). It also reinforces the need for conservative accounting approaches that rely on measured changes in SOC stocks rather than assumptions about long-term persistence of specific carbon fractions (IPCC, 2019).

2.5 Land management practices and SOC dynamics

Land management practices exert a strong influence on soil organic carbon (SOC) dynamics by altering both the quantity and quality of organic carbon inputs to soil and the processes governing carbon losses (Lal et al., 1998; Paustian et al., 1997). Changes in management can therefore lead to gradual increases or decreases in SOC stocks over time (Follett, 2001).

Tillage practices are among the most influential management factors affecting SOC dynamics. Mechanical soil disturbance increases aeration and disrupts soil aggregates, enhancing microbial access to organic matter and accelerating decomposition processes (Vance, 2000). Conversely, reduced tillage and no-tillage systems generally limit physical disturbance, promote aggregate formation, and favor the retention of organic carbon, particularly in surface soil layers (West & Post, 2002).

Cropping systems and crop rotations also play a critical role in SOC dynamics. Systems that increase biomass production, reduce fallow periods, incorporate cover crops, or include perennial vegetation tend to enhance carbon inputs to soil through residues and root systems (Sperow et al., 2003; Follett, 2001). In contrast, simplified or continuous monocropping systems with limited residue return may contribute to SOC depletion over time (Lal et al., 1998).

Residue management practices influence both short-term carbon inputs and longer-term SOC stabilization. The retention and incorporation of crop residues provide a continuous source of organic material that supports microbial activity and contributes to SOC formation (Paustian et al., 1997; Liu et al., 2014). Residue removal or burning reduces carbon inputs and may negatively affect SOC stocks and soil structure (Follett, 2001).

The effects of land management practices on SOC are strongly context-dependent. Soil texture, climate, topography, and historical land use interact with management practices to determine SOC responses (Jobbágy & Jackson, 2000; IPCC, 2019). As a result, similar management interventions may produce different SOC outcomes across sites and regions (IPCC, 2019).

These considerations underscore the importance of site-specific assessment and conservative accounting approaches. The methodology therefore avoids prescriptive assumptions regarding the magnitude or permanence of SOC gains associated with specific land management practices and instead relies on measured changes in SOC stocks to quantify outcomes (IPCC, 2019).

2.6 Anaerobic digestate: production and characteristics

Anaerobic digestion (AD) is a widely applied biological process through which organic materials are transformed into biogas and a residual material commonly referred to as digestate (Appels et al., 2011; Ward et al., 2008). The process relies on the metabolic activity of complex microbial communities operating under anaerobic conditions and is used globally for the treatment of a broad range of organic waste streams (Ward et al., 2008; Da Ros et al., 2016).

Digestate represents a heterogeneous material whose physical, chemical, and biological characteristics depend on multiple factors, including the nature of the input substrates, the configuration and operating conditions of the digestion process, and any post-treatment steps applied prior to land application (Risberg et al., 2017; Zirkler et al., 2014). As a result, digestates derived from different feedstocks or facilities may exhibit substantial variability in nutrient content, organic carbon composition, moisture content, and potential contaminants (Risberg et al., 2017; Zirkler et al., 2014).

Compared to untreated organic feedstocks, digestates typically contain lower concentrations of readily degradable organic carbon due to partial conversion of carbon to biogas during digestion (Möller & Müller, 2012). At the same time, digestates often contain a higher proportion of mineralized nutrients, particularly ammonium nitrogen, which can influence nutrient availability and soil processes following application (Arthurson, 2009).

The agronomic and environmental behavior of digestate following soil application is therefore not uniform and cannot be inferred solely from its origin or digestion technology. Instead, digestate performance reflects an interaction between its intrinsic properties and site-specific soil, climate, and management conditions (Nkoa, 2013; Risberg et al., 2017).

This variability supports the methodological decision not to prescribe specific digestion technologies, retention times, or process parameters. Rather, the methodology requires project proponents to demonstrate that digestate applied under project activities is suitable for land application and consistent with environmental protection and soil health objectives, while allowing flexibility across regional and technological contexts (IPCC, 2019).

2.7 Digestate application and soil carbon interactions

The application of digestate to agricultural soils influences soil organic carbon (SOC) dynamics through multiple, interacting mechanisms related to organic carbon inputs, nutrient availability, and microbial activity. The net effect of digestate application on SOC stocks depends on both the quantity and quality of carbon added and on site-specific soil and management conditions.

Compared to untreated organic feedstocks, digestates generally contain lower concentrations of total organic carbon due to the partial conversion of carbon into biogas during anaerobic digestion (Möller & Müller, 2012; Albuquerque et al., 2012). However, several studies indicate that this reduction in organic carbon content does not necessarily translate into lower SOC stocks following land application. Möller (2015) suggested that reduced degradability of digestate-derived organic matter may partially compensate for lower carbon inputs by slowing post-application decomposition processes.

Evidence from long-term field experiments supports the conclusion that digestate application does not inherently result in SOC depletion when compared with the application of livestock manures or slurries. Studies conducted over multiple years have reported no significant negative impacts on SOC stocks under digestate-based fertilization regimes (Möller, 2009; Bachmann et al., 2014; Thomsen et al., 2013).

The form in which digestate is applied may further influence its interaction with soil carbon processes. Additional treatment steps, such as composting or fractionation, have been shown to increase the proportion of more stabilized organic carbon forms, potentially enhancing the contribution of digestate-derived carbon to SOC sequestration (De la Fuente et al., 2013; Tambone et al., 2010).

Digestate application can also affect SOC dynamics indirectly through changes in nitrogen availability and microbial activity. The relatively high proportion of mineral nitrogen in digestates, particularly ammonium, may stimulate microbial processes and, under certain conditions, induce a priming effect that accelerates the decomposition of existing soil organic matter (Fontaine et al., 2003; Arthurson, 2009). The magnitude and direction of such effects are highly context-dependent and influenced by application rates, soil properties, climate, and complementary carbon inputs.

Overall, the scientific literature indicates that digestate application does not produce uniform SOC outcomes and should not be assumed to automatically increase or decrease SOC stocks. This variability reinforces the need for conservative accounting approaches based on direct

measurement of SOC stock changes over time rather than on assumptions regarding the intrinsic carbon sequestration potential of digestate application.

2.8 Role of crop residues and complementary carbon inputs

Sustained increases in soil organic carbon (SOC) stocks in agricultural systems are rarely achieved through a single source of organic inputs. Instead, SOC dynamics reflect the combined contribution of multiple carbon sources and management practices operating over time (Paustian et al., 1997; Lal et al., 1998).

Crop residues constitute a major and often dominant source of organic carbon inputs to agricultural soils. Aboveground residues and belowground root-derived inputs contribute to SOC formation by supplying organic substrates that support microbial activity and promote the incorporation of carbon into soil organic matter pools (Paustian et al., 1997; Liu et al., 2014). The quantity and quality of residue inputs are therefore critical determinants of SOC trajectories.

Evidence from long-term field studies indicates that maintaining or increasing SOC stocks under digestate-based fertilization regimes frequently requires complementary carbon inputs derived from crop residues. Tiwari et al. (2000) demonstrated that sustained SOC levels over multi-year periods were achieved when digestate or biogas slurry application was combined with the incorporation of crop residues, particularly cereal straw.

Cereal straw and other crop residues play a dual role in SOC dynamics. In addition to providing organic carbon, residues contribute to the recycling of nutrients and influence soil physical properties, including aggregation and moisture retention, which indirectly affect SOC stabilization processes (Liu et al., 2014; Wang et al., 2017). Residue management practices that retain biomass on the field therefore tend to support more favorable SOC outcomes than systems characterized by extensive residue removal.

The interaction between digestate application and crop residue management highlights the importance of considering overall carbon balances rather than isolated inputs. Digestate application may influence nutrient availability and microbial processes, while crop residues provide a sustained carbon supply that supports longer-term SOC formation and stabilization (Bai et al., 2015; Wang et al., 2017).

These findings reinforce the methodological decision to avoid attributing SOC increases solely to digestate application. Instead, the methodology relies on measured changes in SOC stocks that reflect the integrated effects of digestate use, residue management, and other land management practices within the project boundary.

2.9 Measurement approaches and stock-change rationale

Quantification of soil organic carbon (SOC) changes can be approached using different methodological frameworks, including flux-based measurements, model-based simulations, and stock-change assessments. Among these, stock-change approaches based on direct

measurement of SOC stocks are widely recognized as the most robust and transparent option for crediting purposes in agricultural systems (Paustian et al., 1997; IPCC, 2019).

Flux-based approaches, which focus on short-term carbon dioxide exchanges between soil and the atmosphere, are highly sensitive to temporal variability and environmental conditions. As a result, such approaches are generally unsuitable for attributing long-term changes in SOC stocks, particularly in heterogeneous agricultural landscapes (IPCC, 2019).

Model-based approaches can provide valuable insights into SOC dynamics under different land uses and management scenarios. However, model outputs are inherently dependent on assumptions, parameterization, and calibration quality, which may vary substantially across sites and regions (Coleman & Jenkinson, 1996; IPCC, 2019). For this reason, models are best suited to support stratification, scenario analysis, or consistency checks, rather than to serve as the sole basis for credit quantification.

Stock-change approaches rely on repeated measurements of SOC stocks over time within defined soil depths and land units. By comparing SOC stocks measured at successive points in time, this approach directly captures net changes resulting from the integrated effects of land management, organic inputs, and environmental conditions (Paustian et al., 1997; IPCC, 2019). When combined with appropriate sampling design, uncertainty assessment, and conservative adjustment, stock-change methods provide a transparent and verifiable basis for SOC accounting.

International guidance recognizes stock-change measurement as a preferred approach for monitoring SOC changes in managed lands. The IPCC Guidelines for National Greenhouse Gas Inventories and their subsequent refinements emphasize stock-change methods for cropland and grassland systems where direct measurement data are available (IPCC, 2019). Similarly, international MRV guidance highlights the importance of repeated soil sampling, bulk density determination, and stratified sampling designs to capture SOC variability (World Bank, 2021).

The methodological design adopted under this standard reflects these scientific and policy considerations. By prioritizing direct measurement of SOC stocks and applying conservative accounting rules, the methodology aims to minimize reliance on assumptions and to ensure that credited SOC removals are grounded in observable and verifiable changes.

2.10 Models and their supporting role

Process-based and empirical models have been widely developed to simulate soil organic carbon (SOC) dynamics under different land uses, climatic conditions, organic inputs, and management practices. Such models provide valuable insights into the mechanisms governing SOC turnover and stabilization and are commonly used in research and policy contexts (Coleman & Jenkinson, 1996; IPCC, 2019).

Among the most widely applied SOC models is the Rothamsted Carbon Model (RothC), which simulates the decomposition and turnover of organic matter pools as a function of climate,

soil properties, and management inputs (Coleman & Jenkinson, 1996; Coleman, 2009). Similarly, the IPCC Tier 2 steady-state soil carbon methods provide structured approaches for estimating SOC changes at regional or national scales based on land use and management categories (IPCC, 2019).

Despite their utility, SOC models are subject to inherent limitations related to parameter uncertainty, calibration requirements, and sensitivity to site-specific conditions. Model performance depends on the quality and representativeness of input data, including climate records, soil characteristics, and management histories, which may not be uniformly available across project areas (IPCC, 2019).

For these reasons, SOC models are best suited to play a supporting role in SOC accounting frameworks. Within this methodology, models may be used to inform stratification, explore plausible SOC trajectories, or conduct consistency checks. However, model outputs alone are not considered sufficient for the quantification of SOC removals for crediting purposes.

2.11 Limitations, variability and scientific boundaries

Scientific understanding of soil organic carbon (SOC) dynamics recognizes substantial spatial and temporal variability within and across agricultural landscapes. SOC stocks can vary significantly over short distances due to differences in soil texture, mineralogy, topography, and management history, creating challenges for precise quantification (Jobbágy & Jackson, 2000; Bernoux et al., 1998).

Temporal variability further complicates SOC assessment. Inter-annual climate variability, extreme weather events, and episodic disturbances can influence both carbon inputs and decomposition processes, leading to short-term fluctuations in measured SOC stocks that may not reflect long-term trends (Wang et al., 1999; IPCC, 2019).

In addition, soils exhibit finite capacities to stabilize organic carbon. As SOC accumulates, the efficiency with which additional carbon inputs are retained may decline due to saturation of stabilization mechanisms and increased decomposition rates (von Lützow et al., 2008; Dignac et al., 2017). This saturation behavior limits the assumption of indefinite or linear SOC accumulation.

The application of organic amendments, including digestates, may also influence SOC dynamics through indirect effects such as changes in nutrient availability and microbial activity. Under certain conditions, these effects can lead to accelerated decomposition of existing soil organic matter, commonly referred to as priming effects (Fontaine et al., 2003). The magnitude and direction of such effects are highly context-dependent and remain subject to scientific uncertainty.

These sources of variability and uncertainty define clear scientific boundaries for SOC-based mitigation. They underscore the importance of conservative accounting approaches, robust monitoring designs, and explicit uncertainty management. Accordingly, the methodology

prioritizes measured stock changes, applies conservative adjustments, and avoids assumptions regarding permanent or unlimited soil carbon sequestration.

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