



BIOCARBON BIODIVERSITY STANDARD BBS METHODOLOGY

BBS0002

Methodology for Soil Biodiversity Conservation in Agroecosystems

BIOCARBON CERT®

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Acronyms and abbreviations

Acronym	Definition
ASV	Amplicon Sequence Variant
BACI	Before–After–Control–Impact
BBS	BioCarbon Biodiversity Standard
BioCredit	Voluntary Biodiversity Credit
CAB	Conformity Assessment Body
CID	Conservation Initiative Document
FBS	Faunal Biodiversity Score
FPIC	Free, Prior and Informed Consent
GCT	Global CarbonTrace
GIS	Geographic Information System
IPs	Indigenous Peoples
ISO	International Organization for Standardization
LCs	Local Communities
MBC	Microbial Biomass Carbon
MBS	Microbial Biodiversity Score
MDE	Minimum Detectable Effect
PERMANOVA	Permutational Multivariate Analysis of Variance
QA	Quality Assurance
QC	Quality Control
qPCR	Quantitative Polymerase Chain Reaction
SBI	Soil Biodiversity Index
SDGs	Sustainable Development Goals
SDSs	Sustainable Development Safeguards
SOC	Soil Organic Carbon
TOC	Theory of Change
WRB	World Reference Base for Soil Resources

1 Introduction

Soils are living and highly diverse ecosystems that support microorganisms, soil fauna, plant roots and their ecological interactions. Current scientific evidence estimates that soils may contain approximately $59 \pm 15\%$ of the species on Earth. Soil biodiversity contributes to nutrient cycling, organic matter transformation, soil structure, water regulation, plant health, and the control of pests and pathogens (Anthony et al., 2023; FAO et al., 2020).

In agroecosystems, soil biodiversity is influenced by soil properties, climate, vegetation, land-use history and agricultural management. Intensive tillage, compaction, erosion, loss of soil cover, simplified rotations, nutrient imbalance, pesticide exposure, pollution and inappropriate water management may alter the diversity, composition, abundance and trophic structure of soil communities. Because biological responses vary among soils, organisms, seasons and management systems, the effects of an agricultural practice shall be demonstrated within the relevant ecological context.

The BioCarbon Biodiversity Standard (BBS) recognizes preservation, ecological restoration and sustainable use as biodiversity conservation activity categories. This methodology establishes the technical procedures for measuring and quantifying soil biodiversity conservation outcomes generated through these activities in terrestrial agroecosystems.

Soil biodiversity conservation outcomes under this methodology may arise through enhancement or recovery, avoided loss, or maintenance, in accordance with the outcome pathways established under the BBS. In degraded or biologically poor soils, the Initiative will normally demonstrate conservation through the recovery or enhancement of soil biodiversity relative to the applicable baseline or counterfactual. In biologically rich soils under pressure, the Initiative may demonstrate conservation through maintenance or avoided loss, where continued conservation action, stewardship, management, protection, governance, or financing is necessary to sustain soil biodiversity condition.

A management practice shall not, by itself, constitute an eligible biodiversity conservation outcome. BioCredits shall represent verified soil biodiversity conservation outcomes demonstrated for a defined monitoring period, and not the mere implementation of a practice or an isolated positive change in an individual measurement. Direct biological evidence concerning soil microorganisms and soil fauna shall provide the primary basis for determining whether the outcome has occurred. Biological functions, physicochemical soil properties, management practices, environmental variables, and landscape information shall support stratification, interpretation, attribution, safeguards, and uncertainty assessment, but shall not independently generate BioCredits.

2 Objectives

This methodology establishes the procedures and technical requirements for quantifying soil biodiversity conservation outcomes and determining the corresponding Voluntary Biodiversity Credits (BioCredits) generated by eligible activities in agroecosystems.

Specifically, this methodology:

- (a) defines the soil biodiversity components, parameters, and indicators used to assess soil biodiversity;
- (b) identifies the activities that may generate eligible soil biodiversity outcomes;
- (c) establishes the requirements for baseline determination, stratification, sampling, laboratory analysis, and data interpretation;
- (d) establishes the procedures for calculating the Soil Biodiversity Index and quantifying the corresponding BioCredits;
- (e) defines the requirements for demonstrating additionality, monitoring soil biodiversity outcomes, and accounting for uncertainty; and
- (f) supports consistency with the BioCarbon Biodiversity Standard and applicable scientific and technical standards.

3 Scope

This methodology establishes the procedures for quantifying soil biodiversity conservation outcomes and determining the corresponding Voluntary Biodiversity Credits (BioCredits) for Biodiversity Conservation Initiatives implemented in terrestrial agroecosystems. It applies to preservation, ecological restoration, and sustainable-use activities recognized under the BioCarbon Biodiversity Standard (BBS).

The methodology covers direct biological attributes of soil microorganisms and soil fauna, including their diversity, community composition, abundance, biomass, and trophic or functional-group structure. Biological functions, physicochemical soil properties, management practices, environmental pressures, climatic conditions, and landscape attributes may be used to support stratification, interpretation, attribution, uncertainty assessment, and the evaluation of potential adverse effects. These supporting variables do not independently constitute soil biodiversity conservation outcomes.

This methodology applies to:

- (a) annual and perennial croplands;
- (b) managed pastures and silvopastoral systems;
- (c) agroforestry and crop–livestock–forest integration systems;
- (d) agroecological and organic production systems;
- (e) degraded agricultural lands under ecological restoration or rehabilitation; and

- (f) associated conservation areas or landscape elements located within the initiative boundary, where they are directly relevant to the soil biodiversity conservation outcomes assessed.

This methodology may be applied to new initiatives and existing land-management systems where the applicable biodiversity baseline or counterfactual has been established and where the soil biodiversity conservation outcome can be measured and quantified using methods that are valid for the relevant ecological and analytical context.

For the purposes of this methodology, three application contexts shall be distinguished: (a) degraded or biologically poor soils, where the primary outcome pathway will normally be enhancement or recovery; (b) biologically rich soils under pressure, where the primary outcome pathway will normally be maintenance or avoided loss; and (c) agroecosystems in transition, where the applicable outcome pathway shall be determined by the baseline, counterfactual, drivers of change, activities implemented, and monitored biological response.

This methodology does not apply to marine or aquatic sediments, urban soils, or activities involving the conversion or degradation of natural ecosystems. It also does not apply where the claimed outcome is based solely on the implementation of a management practice or on changes in physicochemical soil properties without measured biological evidence.

4 Version

This document constitutes the draft for public consultation of the Methodology for Soil Biodiversity Conservation in Agroecosystems (BBS0002), dated September 15, 2026.

This draft shall not enter into force and shall not be used for the registration of initiatives or the issuance of Voluntary Biodiversity Credits (BioCredits). Following completion of the public consultation and approval by BioCarbon, the official methodology shall identify its version number and effective date.

This methodology may be revised periodically to incorporate scientific, technical, methodological, or editorial updates approved by BioCarbon. Users shall ensure that they consult and apply the most recent official version available on the BioCarbon website.

5 Normative references

The following documents are indispensable for the application of this methodology. For dated references, only the edition cited shall apply. For undated references, the latest edition of the referenced document, including any amendments, shall apply:

- (a) BioCarbon Biodiversity Standard (BBS), current version;
- (b) Audit Manual for Biodiversity Conservation Initiatives, current version; and

- (c) applicable BioCarbon tools, procedures, templates, and registry requirements expressly referenced in this methodology.

Where this methodology requires a specific sampling, laboratory, molecular, bioinformatic, or statistical method, the corresponding standard or protocol shall be identified in the relevant section or appendix.

In the event of inconsistency between this methodology and the BBS, the BBS shall prevail.

6 Applicability conditions

This methodology shall apply to Biodiversity Conservation Initiatives that meet all of the following conditions:

- (a) the initiative is implemented in a terrestrial agroecosystem included within the scope of this methodology;
- (b) the initiative area is clearly delineated, complies with the spatial requirements established by the BBS, and the initiative holder has the rights or authorization required to implement the activities;
- (c) the initiative implements one or more eligible activities described in Section 8;
- (d) soil biodiversity outcomes can be measured and quantified relative to an applicable baseline scenario or counterfactual using the methods established in this methodology;
- (e) the applicable outcome pathway is identified as enhancement or recovery, avoided loss, or maintenance, and is justified in relation to the initial soil biodiversity condition, the applicable baseline or counterfactual, and the conservation activities implemented; and
- (f) the initiative complies with the BBS, the applicable BioCarbon Program documents, and applicable legal and regulatory requirements.

This methodology shall not apply to activities involving the conversion or degradation of natural ecosystems, or where the claimed outcome is based solely on the implementation of a management practice or on changes in physicochemical soil properties without measured biological outcomes.

In addition to the methodology-specific conditions above, the Initiative holder shall comply with all cross-cutting requirements of the BBS, including legal compliance, stakeholder engagement and grievance mechanisms, FPIC where applicable, benefit-sharing, BioCredit ownership and rights, Indigenous and Local Communities Data Sovereignty, SDGs contribution, Sustainable Development Safeguards, climate change adaptation, transparency, independent audit, conformity determination, and Registry requirements.

These requirements shall constitute conditions for eligibility, conformity determination, and issuance where applicable, but shall not be converted into SBI points or used as multipliers of the BioCredit quantity.

7 Soil biodiversity management and theory of change

Soil biodiversity management comprises the planned actions undertaken to prevent biodiversity loss, restore or enhance biological communities, maintain ecological interactions and recover the capacity of soil biota to support ecological processes.

The Initiative holder shall identify the applicable soil biodiversity conservation outcome pathway before baseline approval. For degraded or biologically poor soils, the theory of change shall explain how ecological restoration or sustainable-use activities are expected to recover or enhance direct biological indicators relative to the applicable baseline or counterfactual. For biologically rich soils under pressure, the theory of change shall explain how preservation, sustainable use, stewardship, management, protection, governance, or financing is expected to maintain soil biodiversity condition or avoid its deterioration.

The selected pathway shall determine the evidence required for additionality, attribution, monitoring, uncertainty assessment, and BioCredit quantification. A pathway shall not be selected retrospectively for the purpose of increasing BioCredit issuance.

The implementation of a management practice shall not, by itself, constitute a biodiversity outcome eligible for BioCredit issuance.

7.1 Soil biodiversity objectives

The initiative holder shall define specific and measurable soil biodiversity objectives for each applicable stratum or management unit.

Each objective shall identify:

- (a) the soil biodiversity component or conservation object concerned;
- (b) the pressure, threat, or degradation condition to be addressed;
- (c) the intended soil biodiversity conservation outcome;
- (d) the expected direction and magnitude of ecological change;
- (e) the spatial extent over which the outcome is expected;
- (f) the expected response period and potential ecological time lag;
- (g) the indicators and metrics used to evaluate the outcome; and
- (h) the conditions under which adaptive or corrective action shall be initiated.

Objectives shall be compatible with the ecological characteristics of the soil, climate, vegetation, land-use system, and landscape in which the initiative is implemented.

7.2 Theory of change

The initiative holder shall prepare a credible theory of change that explains how the selected activities are expected to generate the intended biodiversity outcome. The theory of change shall distinguish implementation evidence from ecological results and shall describe the assumptions, external drivers, potential confounding factors, response times and risks associated with each causal linkage:

- (a) the initial soil biodiversity condition;
- (b) direct and underlying drivers of biodiversity loss;
- (c) the selected activities;
- (d) implementation outputs;
- (e) expected changes in soil habitat, disturbance, resources, and environmental pressures;
- (f) expected responses in microorganisms, soil fauna, trophic groups, community composition, or biological functions;
- (g) the intended soil biodiversity outcome; and
- (h) the corresponding BioCredit quantification pathway.

The theory of change shall identify assumptions, external drivers, potential confounding factors, risks, response time, and evidence supporting each causal linkage.

The theory of change shall distinguish:

- (a) implementation indicators, which demonstrate that an activity occurred;
- (b) pressure indicators, which demonstrate that a threat was reduced or managed;
- (c) supporting condition and function indicators, which assist ecological interpretation; and
- (d) direct biodiversity indicators, which provide the primary evidence for BioCredit quantification.

7.3 Causal evidence and adaptive review

For each activity, the initiative holder shall demonstrate that the intervention responds to a pressure identified in the baseline, is suitable for the ecological and management context, was implemented over the declared area and period, and produced an additional outcome consistent with the theory of change. A positive difference between the monitored and baseline conditions in one direct biodiversity dimension shall not compensate for material deterioration in another.

The theory of change shall be reviewed when implementation materially deviates from the approved plan, when pressure indicators or biological responses do not follow the expected trajectory, when a direct biodiversity dimension declines, or when new evidence materially changes the causal assumptions. Adaptive management may modify the intervention and monitoring effort, but it shall not be used retrospectively to change indicators, scoring functions or baselines in a manner that increases issuance.

7.4 Intervention requirements

For each activity, the initiative holder shall demonstrate that the intervention:

- (a) responds to a pressure, threat, or degradation condition identified in the baseline;
- (b) has a scientifically plausible causal relationship with the intended biodiversity outcome;
- (c) is suitable for the soil, climate, land-use system, and ecological context;
- (d) was implemented over the declared area, intensity, and period;
- (e) was implemented in accordance with applicable technical specifications and safeguards;
- (f) generated an additional soil biodiversity conservation outcome measured through the approved direct biological indicators;
- (g) did not generate material deterioration in another direct biodiversity dimension; and
- (h) is supported by maintenance, adaptive-management, and reversal-response measures appropriate to the expected durability of the outcome.

7.5 Implementation records

The initiative holder shall maintain georeferenced records of:

- (a) the location and extent of each activity;
- (b) implementation and maintenance dates;
- (c) equipment, materials, biological inputs, amendments, products, or species used;
- (d) application rates, intensity, frequency, and duration;
- (e) responsible persons or entities;
- (f) deviations from the approved implementation plan;
- (g) relevant climatic and soil conditions at the time of implementation;
- (h) observed implementation failures or unintended effects; and
- (i) corrective measures.

Implementation records shall be linked to the applicable strata, sampling units, monitoring results, and calculation files.

7.6 Adaptive management

The initiative holder shall establish decision rules for adapting management where:

- (a) activities are not implemented as planned;
- (b) pressure indicators do not respond as expected;
- (c) direct biological indicators do not demonstrate the expected trajectory;
- (d) a direct biodiversity dimension declines materially;
- (e) supporting soil conditions become unsuitable;
- (f) adverse environmental or social impacts are detected; or
- (g) new information materially changes the theory of change.

Adaptive management shall not be used to modify indicators, scoring functions, baselines, or calculation procedures retrospectively in a manner that increases BioCredit issuance.

Adaptive-management decisions and the measures implemented shall be documented and reported in accordance with Sections 13.14 and 13.15.

8 Soil conservation, restoration and sustainable use activities

Activities implemented under this methodology shall be classified as preservation, ecological restoration, or sustainable use, in accordance with the activity categories established by the BBS. An initiative may implement activities from more than one category, provided that each activity is clearly identified in the Conservation Initiative Document and that the same biodiversity conservation outcome is not counted more than once.

The activities listed in this section are indicative rather than automatically eligible. Final eligibility shall depend on ecological context, implementation quality, safeguards, additionality, and measured biological outcomes.

8.1 Preservation activities

Preservation activities shall aim to maintain the ecological structure, composition, and functions of soil biological communities by preventing or reducing pressures that could cause their degradation. In accordance with the BBS, preservation may include actions that maintain biodiversity and ecosystem condition by limiting or eliminating harmful human intervention.

Eligible preservation activities may include:

- (a) protection of natural or semi-natural areas and their associated soils within the initiative boundary;
- (b) protection of riparian buffers, hedgerows, shelterbelts, windbreaks, field margins, ecological corridors, and other habitat elements relevant to soil biodiversity;
- (c) prevention or reduction of soil erosion, sealing, compaction, salinization, acidification, contamination, or loss of organic horizons;
- (d) restriction of activities that cause excessive mechanical disturbance, vegetation removal, biomass extraction, or degradation of soil habitat;
- (e) prevention of recurrent burning of crop residues or vegetation where burning adversely affects soil biodiversity;
- (f) surveillance and control measures intended to prevent contamination, unauthorized disturbance, or the introduction and spread of invasive alien species; and
- (g) other scientifically justified actions that maintain soil biodiversity relative to the applicable baseline scenario.

Where preservation activities concern landscape elements, their inclusion shall be consistent with the requirements applicable to Landscape Management Tools under the BBS and shall have a demonstrated relationship with the soil biodiversity outcome assessed.

8.2 Ecological restoration activities

Ecological restoration activities shall assist the recovery of soil ecosystems that have been degraded, damaged, or altered. Such activities shall seek to restore biological communities, ecological interactions, habitat conditions, and the capacity of soil biota to support self-sustaining ecological processes over time. This category shall be applied consistently with the ecological restoration provisions of the BBS.

Eligible ecological restoration activities may include:

- (a) rehabilitation of eroded, compacted, structurally degraded, salinized, acidified, contaminated, or biologically depleted agricultural soils;
- (b) re-establishment of permanent or seasonal vegetative cover and diverse root systems;
- (c) restoration of degraded pastures using ecologically appropriate plant communities and management practices;
- (d) re-establishment of agroforestry, silvopastoral, or crop–livestock–forest elements that restore soil habitat and ecological interactions;
- (e) restoration of riparian soils, field margins, shelterbelts, corridors, and other associated habitat elements;
- (f) recovery of organic matter inputs, litter layers, and habitat resources required by soil biological communities;
- (g) remediation of contaminated soils using methods that restore biological condition and do not cause additional environmental harm;
- (h) recovery of soil hydrological conditions where altered drainage, waterlogging, or excessive drying is a demonstrated driver of degradation; and
- (i) other scientifically justified actions that assist the recovery of soil biodiversity and ecological functioning.

Improvement in soil structure, nutrient status, organic carbon, moisture, or another supporting condition shall not, by itself, constitute an ecological restoration outcome. A corresponding response in the direct biological indicators shall be demonstrated.

8.3 Sustainable-use activities

Sustainable-use activities shall enable the productive use of agroecosystems in a manner and at a rate that do not lead to the long-term decline of soil biodiversity. These activities shall maintain the capacity of soil biological communities to support present and future ecological and productive functions, in accordance with the sustainable-use provisions of the BBS.

Eligible sustainable-use activities may include:

- (a) diversified crop rotations, intercropping, relay cropping, mixed cropping, and other systems that increase plant and root diversity;
- (b) establishment and management of cover crops and the maintenance of living roots during a greater proportion of the production cycle;

- (c) reduced-tillage or no-tillage systems designed to reduce the net ecological pressure on soil organisms;
- (d) retention and responsible management of crop residues;
- (e) integrated nutrient management, nutrient recycling, composting, and responsible organic-soil management;
- (f) integrated pest management and measures that reduce the ecological risks associated with pesticides and other agricultural inputs;
- (g) adaptive or rotational grazing systems that maintain soil cover, avoid excessive trampling, and provide adequate recovery periods;
- (h) agroecological, organic, agroforestry, silvopastoral, and integrated crop-livestock-forest production systems;
- (i) controlled traffic and other measures intended to prevent or reduce soil compaction;
- (j) irrigation and drainage management that maintains soil conditions suitable for biological communities;
- (k) measures to prevent erosion, burning, contamination, and the loss of biologically active soil; and
- (l) other sustainable agricultural practices aligned with the soil biodiversity objectives of the initiative.

Participation in an agricultural certification scheme, or the use of terms such as organic, agroecological, regenerative, or sustainable, shall not automatically demonstrate eligibility or a soil biodiversity conservation outcome.

8.4 Activity-specific conditions

8.4.1 Organic amendments and biochar

The use of compost, manure, vermicompost, crop residues, biochar, or other organic amendments shall be supported by information on origin, composition, processing, quality, contaminant concentrations, nutrient content, application rate, and date of application. The initiative holder shall assess potential risks associated with pathogens, heavy metals, persistent contaminants, plastics, salinity, nutrient loading, pH alteration, and displacement of environmental impacts to the area from which the material was sourced.

BioCredits shall not be quantified on the basis of the quantity of amendment applied, the associated increase in soil organic carbon, or a temporary increase in microbial activity following application. The initiative shall demonstrate a measurable and persistent response in the approved direct biological indicators.

8.4.2 Microbial inoculants and mycorrhizal products

The use of microbial inoculants, mycorrhizal products, or other biological inputs shall require documentation of organism identity, origin, quality, viability, intended function, legal status, traceability, biosafety, ecological suitability, and compatibility with the receiving soil domain.

Organisms that are invasive, pathogenic, genetically unstable, ecologically inappropriate, or likely to displace native or resident soil communities shall not be used.

Deliberately introduced organisms shall be identified in molecular or microbiological datasets where technically feasible and where they could influence the measured result. Their detection, abundance, or sequence reads shall not, by themselves, constitute an increase in soil biodiversity or increase the Microbial Biodiversity Score. The initiative holder shall assess the effect of including and excluding deliberately introduced organisms from the applicable calculations, and the more conservative result shall be used unless BioCarbon approves another treatment. Quantification shall be based on the broader and sustained response of the resident biological community.

8.4.3 Reduced tillage and no-tillage

Reduced-tillage and no-tillage activities shall be evaluated according to their net effect on soil biodiversity. The assessment shall consider changes in tillage depth and frequency, machinery traffic, compaction, residue management, crop diversity, soil moisture, and the type, toxicity, frequency, and application rate of herbicides or other pesticides.

A reduction in mechanical disturbance shall not be considered an eligible conservation outcome where it is accompanied by an increase in chemical exposure, compaction, or another pressure that causes material deterioration in soil biological communities.

8.4.4 Hydrological interventions

Hydrological interventions shall be eligible only where altered water conditions are identified as a material driver of soil biodiversity degradation and where the intervention falls within the scope of this methodology. The initiative holder shall assess effects on neighboring land, water quality, soil aeration, greenhouse-gas fluxes, invasive species, existing biological communities, and applicable water rights.

The hydrological condition and the associated soil biodiversity response shall be monitored using methods appropriate to the intervention and ecological context.

8.5 Ineligible activities

The following activities shall not be eligible under this methodology:

- (a) conversion, clearance, drainage, or degradation of natural ecosystems to establish or expand agricultural production;
- (b) intentional degradation of soil biodiversity intended to create a subsequent BioCredit issuance opportunity;
- (c) soil sealing, permanent removal of biologically active soil, or activities that cause irreversible loss of soil habitat;
- (d) introduction or facilitation of invasive alien species, pathogens, or ecologically inappropriate organisms;

- (e) application or disposal of untreated wastes, sewage sludge, industrial residues, contaminated materials, or other substances that create unacceptable environmental or sanitary risks;
- (f) management practices that result in a material net increase in contamination, erosion, compaction, salinization, acidification, or ecotoxicological risk;
- (g) activities whose claimed outcome is based solely on implementation records, expenditure, certification status, reduced input use, soil organic carbon, physicochemical soil properties, microbial biomass, enzyme activity, or another supporting variable without measured direct biological evidence;
- (h) activities implemented outside the ecological, analytical, or reference domain for which the selected indicators and methods are valid; and
- (i) activities that cause material adverse effects on biodiversity, ecosystem integrity, water resources, or the rights and well-being of affected stakeholders.

9 Baseline scenario

The baseline scenario represents the most plausible condition and trajectory of soil biodiversity in the absence of the initiative. It provides the basis against which monitored soil biodiversity conservation outcomes shall be compared and quantified.

For degraded or biologically poor soils, the baseline shall characterize the impaired soil biodiversity condition and the most plausible trajectory of that condition in the absence of the Initiative. For biologically rich soils under pressure, the baseline or counterfactual shall characterize the existing soil biodiversity condition and the credible risk of deterioration, degradation, loss, or insufficient conservation in the absence of continued conservation action. In both cases, the baseline shall support the assessment of the applicable outcome pathway and shall not be replaced by a general assertion that agricultural soils are either degraded or threatened.

The baseline scenario shall be established using pre-specified methods, assumptions, and data before the corresponding monitoring results are evaluated. It shall be transparent, scientifically justified, conservative, and capable of independent audit.

The initial condition, baseline scenario, control area, and ecological reference are related but distinct concepts. The initial condition is the measured state of soil biodiversity at the beginning of the quantification period. The baseline scenario describes how that condition would most plausibly change in the absence of the initiative. A control area is a contemporaneously monitored area used to estimate that trajectory. An ecological reference describes a comparatively intact, desired, or potentially attainable condition and shall not automatically be treated as the baseline scenario or control.

The quantification period shall be aligned with the date represented by the approved baseline, in accordance with the BBS. Soil biodiversity conservation outcomes shall not be quantified for periods for which an applicable baseline and adequate monitoring data are unavailable.

9.1 Baseline framework and minimum data

Baseline determination shall combine direct biological measurements, supporting soil and environmental information, land-use and management history, identified drivers and pressures, and an explicit representation of the condition expected without the initiative. The information shall be sufficient to characterize material spatial and temporal variability and to support subsequent monitoring under comparable conditions.

At minimum, the baseline shall include:

- (a) the initial condition of the direct microbial and soil-fauna indicators required under Section II;
- (b) relevant biological-function and biomass indicators used to interpret the biological condition;
- (c) soil habitat and physicochemical variables required for stratification, comparability, attribution, and the assessment of potential adverse effects;
- (d) land use, vegetation, agricultural production systems, and management practices within the initiative area;
- (e) direct and underlying drivers of soil biodiversity transformation or loss, including the pressures addressed by the initiative;
- (f) climatic, hydrological, topographic, and landscape conditions relevant to the selected indicators;
- (g) the expected continuation or modification of land use and management in the absence of the initiative;
- (h) control, comparison, or ecological reference information, where applicable; and
- (i) the principal sources of uncertainty affecting the baseline scenario.

The baseline shall produce an expected condition or trajectory for the approved direct biological indicators and the Soil Biodiversity Index for each applicable stratum and monitoring period. Supporting variables shall assist the construction and interpretation of the baseline but shall not substitute for direct biological information.

Measurements used to establish the baseline shall be obtained using the same or demonstrably comparable sampling depths, seasonal windows, field methods, analytical procedures, molecular platforms, bioinformatic processes, and reporting units intended for subsequent monitoring.

9.2 Historical evidence

The initiative holder shall document the land-use and management history necessary to establish the most plausible scenario in the absence of the initiative. Where reliable records

exist, the historical assessment shall cover at least the five years preceding the initiative start date or the beginning of the applicable quantification period.

Historical evidence may include farm and land-management records, crop and livestock records, input purchase and application records, official agricultural or environmental information, previous monitoring data, satellite imagery, aerial photography, land-cover maps, and interviews corroborated by independent evidence.

The historical assessment shall address, as applicable, crop rotations, tillage, traffic, grazing, irrigation, drainage, fertilizer and pesticide use, residue management, organic amendments, fire, erosion, contamination, changes in vegetative cover, and previous conservation or restoration activities.

Where complete historical records are unavailable, the initiative holder shall document the information gap, use the longest reliable period available, triangulate multiple sources of evidence, and apply conservative assumptions. The initial measured condition shall not be assumed to represent the baseline scenario without supporting evidence concerning the expected trajectory in the absence of the initiative.

9.3 Counterfactual, control, and ecological reference

A representative control area shall be used where it is technically and practically feasible. The control shall represent the land use and management expected without the initiative and shall be comparable in soil, climate, hydrology, topography, land-use history, and landscape context.

Control areas shall be sufficiently separated from the activities to avoid material influence from the initiative. They shall be monitored using the same sampling design, indicator modules, sampling depths, temporal windows, analytical methods, and QA/QC procedures applied within the initiative area.

Where a physical control area is not feasible, the initiative holder may propose a historical, modeled, matched, or synthetic counterfactual. The selected approach shall be scientifically justified, use verifiable data, account for relevant ecological and management trends, quantify model and structural uncertainty, and apply conservative assumptions. The approach shall be defined before the corresponding monitoring results are evaluated.

For preservation activities, a baseline involving expected deterioration shall be used only where the identified drivers and available evidence demonstrate that such deterioration is plausible within the relevant period. A general assertion that agricultural soils are threatened shall not be sufficient to establish a declining baseline.

For ecological restoration and sustainable-use activities, the baseline shall reflect the expected continuation of pre-initiative land use and management, together with natural variation and external trends that would plausibly affect soil biodiversity.

Ecological reference areas may be used to characterize ecological potential, establish reference domains, develop scoring functions, or assess community similarity. A native or minimally disturbed area shall not be used as the counterfactual unless evidence demonstrates that it represents the condition that would most plausibly occur without the initiative.

9.4 Stratification

The initiative area shall be stratified where material differences in soil, ecological setting, land use, management, degradation, or expected biological response would otherwise affect the representativeness or interpretation of the baseline.

Stratification shall consider, as applicable:

- (a) soil group, parent material, texture, effective depth, drainage, and organic or mineral condition;
- (b) climate, ecological zone, elevation, slope, topographic position, and hydrological regime;
- (c) land use, vegetation type, crop or pasture system, and associated habitat elements;
- (d) management history and intensity, including tillage, inputs, irrigation, drainage, grazing, and residue management;
- (e) existing soil degradation, contamination, erosion, compaction, salinity, or other relevant pressures;
- (f) the conservation activity category and the specific actions implemented; and
- (g) the date or stage of activity implementation.

Soil classification shall follow the World Reference Base for Soil Resources or a documented national system mapped to the applicable WRB classification (IUSS Working Group WRB, 2022).

Each stratum shall be sufficiently homogeneous for the intended analysis and clearly distinguishable from other strata. The number of strata shall reflect material heterogeneity and the capacity of the sampling design to estimate biodiversity conditions within each stratum. No universal minimum or maximum number of strata shall apply.

Strata shall be established before analysis of the monitored outcomes. They shall not be divided, merged, or redefined retrospectively for the purpose of increasing the quantified soil biodiversity conservation outcome.

9.5 Baseline sampling and statistical analysis

Baseline sampling shall follow Appendix B. The design shall represent all applicable strata, distinguish independent field replication from subsampling and laboratory replication, and provide sufficient data to estimate spatial and temporal variability and the uncertainty of the baseline.

Sampling locations shall be selected using a probability-based or another statistically justified design. Sample size shall be determined through power analysis, simulation, or an equivalent procedure using the expected variability of the primary indicators, the selected significance level, the required statistical power, the structure of the sampling design, and a pre-specified target effect size for power-analysis purposes.

The target effect size shall represent the smallest change that the sampling design is intended to detect reliably under the specified statistical assumptions. It may be informed by the initiative's ecological objectives, relevant scientific evidence, previous monitoring data, or pilot results, but it shall be treated as a statistical design parameter. It shall not automatically constitute the ecological materiality threshold applied under Sections 11.14 or 12.3.

Where adequate prior information on indicator variability is unavailable, a pilot survey shall be conducted. Following completion of the sampling design, the initiative holder shall estimate and report the achieved minimum detectable effect for each primary indicator or direct biodiversity dimension, taking into account the final sample size, observed or assumed variance, significance level, statistical power, repeated-measure correlation, spatial structure, and expected sample loss.

The achieved minimum detectable effect shall be used to evaluate the statistical sensitivity of the monitoring design and to interpret a failure to detect change. It shall not, by itself, determine whether an observed change is ecologically material or eligible for BioCredit quantification.

The baseline shall include the direct biological indicator modules required under Section 11. Sampling shall also collect the supporting variables necessary to interpret biological differences, evaluate comparability, and account for material confounding factors.

Where seasonal variation is material, the baseline shall include the relevant seasonal or production-cycle windows. Initiative and control areas shall be sampled within equivalent temporal conditions.

Before the first comparison with monitored results, the initiative holder shall establish a statistical analysis plan. The plan shall define the primary indicators, statistical models, treatment of strata and repeated observations, relevant covariates, spatial and temporal correlation, multivariate and compositional analyses, missing-data procedures, uncertainty propagation, the target effect size used for sample-size determination, the achieved minimum detectable effect, and the criteria used to determine whether the monitored condition exceeds the applicable baseline condition. Ecological materiality shall be assessed separately in accordance with Sections 11.14 and 12.3.

9.6 Baseline documentation, validity, and reassessment

The baseline scenario shall be documented in the Conservation Initiative Document or in a dedicated Baseline Report. The documentation shall include:

- (a) the initial soil biodiversity condition;
- (b) the justification and evidence supporting the selected baseline scenario;
- (c) the land-use and management history;
- (d) the identified drivers and pressures;
- (e) the stratification and sampling design;
- (f) the location and characterization of initiative, control, comparison, and ecological reference areas, where applicable;
- (g) the field, laboratory, molecular, bioinformatic, and statistical methods applied;
- (h) the applicable QA/QC procedures;
- (i) the analysis of spatial and temporal variability and uncertainty;
- (j) the expected trajectory of the direct biological indicators and the Soil Biodiversity Index;
- (k) maps of the initiative boundary, strata, sampling units, control areas, reference areas, and excluded areas; and
- (l) relevant data gaps, assumptions, limitations, and conservative treatments.

Spatial interpolation of soil biodiversity indicators shall be used only where the sampling density, observed spatial structure, and selected geostatistical method support a reliable analysis. Interpolated maps shall not replace direct observations or independently justify the inclusion of unsampled areas.

The baseline shall remain applicable while the assumptions, drivers, management conditions, and external factors on which it was established remain materially valid. The initiative holder shall assess baseline validity throughout the quantification period and shall reassess it when material ecological, management, legal, social, or economic changes could alter the condition expected without the initiative.

Reassessment shall also occur where a control area is lost or materially altered, the original counterfactual is no longer plausible, the initiative area or activities change materially, or a methodological change affects the comparability of baseline and monitoring results.

Any update or adjustment to the baseline shall be documented, scientifically justified, applied consistently, and subject to the applicable independent audit and BioCarbon conformity determination. Baseline adjustments shall not be used to artificially increase the quantification or issuance of BioCredits.

Where retroactivity is applied, the baseline shall accurately represent the soil biodiversity condition at the applicable retroactive date, and the historical monitoring data, sampling methods, safeguards, and supporting records shall comply with the retroactivity requirements of the BBS. No soil biodiversity conservation outcome shall be quantified for a retroactive period lacking a valid baseline or complete, verifiable, and auditable monitoring data.

10 Additionality

A soil biodiversity conservation outcome is additional where it occurs as a direct result of the implementation of the initiative and would not have occurred under the applicable baseline scenario. Additionality shall be demonstrated through a qualitative and quantitative assessment of the relationship between the conservation activities implemented and the soil biodiversity outcomes measured during monitoring.

The assessment shall use the baseline established under Section 9, the direct biological indicators defined in Section 11, and the monitoring data collected in accordance with Section 13. Supporting biological-function, soil-condition, management, pressure, climatic, and landscape variables may be used to explain the observed response and account for confounding factors, but shall not substitute for direct biological evidence.

Additionality shall be demonstrated in relation to the applicable outcome pathway. For enhancement or recovery, the Initiative holder shall demonstrate that the monitored soil biodiversity condition reflects a measurable recovery or improvement relative to the applicable baseline or counterfactual. For avoided loss, the Initiative holder shall demonstrate a credible expected decline in the absence of the Initiative and show that the Initiative materially prevented or reduced that decline. For maintenance, the Initiative holder shall demonstrate that continued conservation action, stewardship, management, protection, governance, or financing was necessary to sustain the soil biodiversity condition relative to the baseline or counterfactual.

10.1 Demonstration of additionality

The additionality assessment shall include, at a minimum:

- (a) identification of a baseline representing the most plausible condition and trajectory of soil biodiversity in the absence of the initiative;
- (b) comparison of the baseline with the monitored condition, demonstrating a measurable soil biodiversity conservation outcome that exceeds the applicable baseline condition and is directly attributable to the initiative;
- (c) evidence that the observed soil biodiversity conservation outcome cannot be fully explained by external drivers, public policies, legally required actions, natural variability, or unrelated changes in land use or management; and
- (d) justification of the causal mechanisms linking the conservation activities to the monitored biological response.

For preservation activities, the soil biodiversity conservation outcome shall be determined by comparing the monitored condition with the condition expected under the applicable baseline scenario. Preservation may generate an additional outcome where the monitored condition exceeds the baseline condition, including where the initiative prevents a deterioration that would otherwise have occurred.

For ecological restoration and sustainable-use activities, the initiative holder shall demonstrate that the monitored soil biodiversity condition exceeds the applicable baseline condition and that the observed outcome is attributable to the activities implemented.

10.2 Legal and policy requirements

Activities that are legally required or mandated by public policy shall not be considered additional.

Where an initiative includes both required and voluntary actions, the initiative holder shall distinguish them clearly and shall demonstrate that the quantified soil biodiversity conservation outcome is attributable to the voluntary actions. Outcomes resulting solely from compliance with an applicable legal, regulatory, licensing, contractual, or public-policy obligation shall not be quantified as additional.

Changes in legal or policy requirements during the quantification period shall be assessed to determine whether they affect the continued additionality of the initiative.

10.3 Attribution and causal evidence

The initiative holder shall use multiple lines of evidence to demonstrate that the monitored outcome results from the initiative rather than from background variation or external influences. The evidence shall include, as applicable:

- (a) documented implementation of the conservation activities at the declared location, extent, intensity, and time;
- (b) evidence of a change in the pressure, threat, or degradation condition identified in the baseline and the theory of change;
- (c) quantitative comparison of direct biological indicators between the monitored condition and the applicable baseline, control, or modeled counterfactual;
- (d) temporal and spatial consistency between activity implementation, changes in pressures or soil conditions, and the observed biological response; and
- (e) analysis of climatic, hydrological, management, land-use, and other factors capable of explaining the observed change.

Where feasible, attribution shall be assessed through a before–after–control–impact design, matched control areas, repeated-measures analysis, treatment-by-time effects, or another scientifically justified causal approach established before the monitoring results are evaluated.

A simple before-and-after comparison, a correlation between an activity and an indicator, or an improvement in soil organic carbon, enzyme activity, microbial biomass, vegetation cover, or another supporting variable shall not, by itself, demonstrate additionality.

Evidence concerning common practice, implementation barriers, historical management decisions, investment conditions, technical constraints, or initiative-specific incentives may supplement the assessment. Such evidence shall not replace the demonstration of a

measurable biological outcome or constitute an independent mandatory test unless expressly required by the BBS or another applicable BioCarbon normative document.

10.4 Prevention of artificial additionality

The initiative holder shall demonstrate that neither the initiative holder nor a related party deliberately degraded soil biodiversity within the claimed area in order to create a subsequent opportunity for BioCredit issuance.

The assessment shall cover the historical period used to establish the baseline and, where applicable, the retroactive period permitted under the BBS. It shall consider land-use change, removal of vegetative cover, intensification of disturbance, contamination, burning, excessive grazing, deliberate cessation of beneficial management, and other actions capable of artificially reducing the initial biological condition.

Where credible evidence of deliberate degradation exists, the affected area shall be excluded from quantification unless the initiative holder demonstrates that the degradation was unrelated to the proposed initiative and BioCarbon accepts its inclusion through the applicable conformity determination process.

10.5 Temporal consistency

The monitored outcome shall be observed over a period sufficient to distinguish a persistent soil biodiversity response from short-term biological fluctuation.

Unless a longer response period is established in the theory of change, the outcome shall be assessed over at least one complete production or management cycle following implementation of the relevant conservation activity. Temporary responses occurring immediately after fertilization, irrigation, application of an organic amendment, microbial inoculation, disturbance, or another short-term event shall not, by themselves, demonstrate additionality.

The monitoring period, seasonal window, sampling depth, analytical methods, and statistical treatment shall remain comparable with those used to establish the baseline.

10.6 Documentation and reassessment

The initiative holder shall document all data, assumptions, methods, evidence, and analytical results used to demonstrate additionality in the Conservation Initiative Document, the Baseline Report, or the applicable Monitoring Report.

Additionality shall be reassessed where there is a material change in:

- (a) the applicable legal or policy framework;
- (b) the baseline scenario or the validity of the counterfactual;
- (c) land use, management, climate, hydrology, or other external drivers;
- (d) the conservation activities implemented; or

- (e) another condition that could materially affect whether the monitored outcome would have occurred in the absence of the initiative.

A change that removes or materially reduces additionality shall affect prospective BioCredit quantification and issuance. All overlapping standards, programs, public accounting frameworks, compensation schemes, or other crediting mechanisms shall be disclosed and addressed in accordance with the BBS requirements for outcome integrity, attribution, and prevention of double counting.

11 Indicators and metrics

This section establishes the indicators and procedures used to characterize soil biodiversity condition and calculate the Soil Biodiversity Index (SBI) for each stratum and monitoring time. The SBI provides standardized evidence of the condition of direct soil biodiversity indicators and supports the quantification of verified soil biodiversity conservation outcomes under Section 12. SBI values, SBI differences, or individual indicator changes shall not, by themselves, constitute BioCredits.

The indicator framework distinguishes direct biological indicators from supporting variables. Direct microbial and soil-fauna indicators shall form the Microbial Biodiversity Score (MBS), the Faunal Biodiversity Score (FBS), and the SBI. Biological functions, physicochemical soil properties, management practices, environmental pressures, climatic conditions, and landscape attributes shall support stratification, interpretation, causal attribution, uncertainty assessment, risk assessment, and adaptive management. They shall not independently generate BioCredits or be added to the SBI.

The SBI addresses the ecological soil-biodiversity component of the biodiversity conservation outcome. Socio-cultural dimensions, rights, participation, safeguards, and Data Sovereignty shall be assessed in accordance with the BBS and the applicable BioCarbon Program documents and shall not be converted into SBI points.

Table 1. Indicator framework and role in the methodology

Indicator group	Examples	Role
Direct microbial biodiversity	Bacterial, archaeal and fungal diversity; community composition; beta diversity; similarity to control or reference.	Forms the Microbial Biodiversity Score.
Direct soil-fauna biodiversity	Nematodes, microarthropods, earthworms, macrofauna or another approved faunal group; abundance, biomass, diversity, trophic or functional structure.	Forms the Faunal Biodiversity Score.

Indicator group	Examples	Role
Biological functions and biomass	Microbial biomass carbon, respiration, decomposition and relevant enzyme or nutrient-cycle processes.	Supports interpretation and causal evidence; does not directly increase the SBI.
Soil habitat and physicochemical condition	Texture, moisture, bulk density, pH, electrical conductivity, SOC, nitrogen, phosphorus, temperature and material contaminants.	Supports stratification, comparability and no-harm assessment.
Management, pressure and context	Tillage, cover, crop diversity, fertilizers, pesticides, grazing, irrigation, climate, land cover and connectivity.	Supports implementation evidence, attribution, leakage and adaptive management.
Landscape and climatic context	Precipitation, temperature, drought, land cover, topography, hydrology, habitat proximity, and connectivity	Supports interpretation of external drivers and spatial context

11.1 Indicator-selection principles

Indicators shall be selected in relation to the soil biodiversity objectives, the drivers and pressures identified in the baseline, the activities included in the theory of change, and the ecological characteristics of the initiative area.

Each indicator used under this methodology shall:

- correspond to a defined soil biodiversity objective, conservation object, pressure, or risk;
- be scientifically relevant to the applicable soil, ecological, and management context;
- be capable of responding within the expected monitoring period;
- have a documented and validated sampling and analytical method;
- have an ecologically interpretable direction or target condition;
- have known or quantifiable sources of uncertainty;
- be reproducible and comparable between baseline and monitoring periods;
- avoid unnecessary duplication with highly correlated indicators;
- be supported by an approved reference domain and scoring function; and
- be capable of independent audit.

Before baseline analysis, the initiative holder shall prepare an Indicator Dictionary. For each indicator, the Indicator Dictionary shall specify its name, conservation object, ecological rationale, method, unit, sampling depth, temporal window, reporting frequency, taxonomic or functional resolution, scoring function, reference domain, direction of response, weight,

uncertainty, QA/QC requirements, data source, applicable materiality threshold, and status as a primary, supporting, or critical indicator.

Primary direct biological indicators shall contribute to the MBS or FBS. Supporting variables shall assist stratification, interpretation, attribution, safeguards, uncertainty assessment, or risk assessment but shall not enter the SBI. Critical direct biological indicators shall be those for which a material adverse change would invalidate or restrict positive BioCredit quantification.

The approved indicator set, reference domains, scoring functions, transformations, taxonomic resolution, weights, and aggregation procedures shall remain fixed throughout the applicable quantification period. Any proposed material change shall be documented and submitted to BioCarbon in accordance with the BBS. Where a change is approved, the affected baseline information, monitored values, reference-domain parameters, scoring functions, and pathway-specific eligibility assessment shall be recalculated or reassessed using a common and comparable procedure before the soil biodiversity conservation outcome is determined under Section 12.

Indicator sets shall be assessed for conceptual, statistical, and ecological redundancy before inclusion in the SBI. Indicators derived from the same underlying biological distribution, sample, or data source shall not be treated as independent evidence solely because they are expressed through different mathematical transformations. Where multiple metrics quantify substantially overlapping attributes, the Initiative holder shall document the rationale for retaining them and demonstrate that their inclusion does not result in disproportionate weighting or double representation of the same soil biodiversity attribute.

11.2 Direct biological indicator modules

Each initiative shall assess both microbial and soil-fauna biodiversity. The microbial dimension shall include bacterial and archaeal communities and fungal communities. The faunal dimension shall include at least one standardized soil-fauna module selected according to the theory of change, soil conditions, land use, biogeographic context, and relevant pressures.

A second faunal module shall be included where one group does not adequately represent the expected biological response, trophic structure, spatial variability, or identified risk. The initiative holder shall justify the selected faunal module or modules in the Indicator Dictionary before baseline sampling.

Table 2. Direct biological modules and minimum reported metrics

Component	Default or approved method	Minimum reported metrics
Bacteria and archaea	16S rRNA gene amplicon sequencing, using a validated DNA-extraction and bioinformatic procedure, or a BioCarbon-approved equivalent.	Sample-coverage information, coverage-standardized Hill diversity, community composition, beta diversity, and similarity to an approved ecological reference.
Fungi	ITS amplicon sequencing, preferably using a validated ITS2 region or another approved marker.	Sample-coverage information, coverage-standardized Hill diversity, community composition, beta diversity, ecological-reference similarity, and functional-guild information where sufficiently reliable.
Primary soil-fauna module	Nematodes, microarthropods, earthworms, macrofauna, or another BioCarbon-approved faunal group, using the applicable standardized method.	Abundance or biomass, diversity, community composition, and ecologically relevant trophic or functional groups.
Additional direct module, when required	A second standardized faunal group selected in accordance with the theory of change and reference domain.	Metrics defined in the Indicator Dictionary and approved before baseline establishment.

The modular combination of microbial, faunal, and functional observations is consistent with international efforts to harmonize soil-biodiversity monitoring while allowing adaptation to ecological context (Parnell et al., 2025).

An initiative shall not omit an entire direct biological dimension solely because of cost, logistical constraints, or limited laboratory availability. Where a default method is demonstrably unsuitable for the applicable ecological context, the initiative holder may propose an alternative direct biological method. The alternative shall provide equivalent or greater ecological information, shall be validated for the intended purpose, and shall receive BioCarbon approval before baseline establishment.

The same direct biological modules, methods, sampling depths, temporal windows, taxonomic resolution, scoring procedures, and weights shall be applied to the baseline and monitored conditions.

11.3 Microbial-community methods

11.3.1 Sample processing

Soil intended for molecular analysis shall be collected using sterile or appropriately decontaminated equipment, homogenized using a documented procedure, preserved immediately, transported under controlled conditions, and processed within the validated holding time.

DNA extraction shall follow ISO 11063 or an equivalent validated method. The selected extraction procedure shall be appropriate for the relevant soil types and shall remain consistent between baseline and monitoring periods.

The initiative holder shall record the sample mass, homogenization procedure, preservation method, storage temperature, holding time, extraction batch, extraction yield, DNA-quality indicators, and all deviations from the approved procedure.

11.3.2 Amplicon sequencing

Bacterial and archaeal communities shall be assessed using an appropriate region of the 16S rRNA gene. Fungal communities shall be assessed using an appropriate ITS region.

Amplicon-sequencing data are compositional and shall be analyzed using methods appropriate to relative multivariate data; raw read proportions shall not be interpreted as absolute organism abundance (Gloor et al., 2017). Amplicon sequencing shall be described as metabarcoding or amplicon sequencing and shall not be referred to as shotgun metagenomics.

Because amplicon-sequencing datasets are compositional, analyses based on relative sequence data shall use statistical transformations, distance metrics, and multivariate methods appropriate to the data structure, ecological question, taxonomic resolution, treatment of zero values, rare taxa, contaminants, and sequencing depth. Log-ratio approaches, including centered log-ratio transformation, Aitchison distance, or other scientifically justified alternatives, may be used where appropriate. The selected approach shall be pre-specified in the statistical analysis plan and sensitivity to alternative valid transformations or distance metrics shall be assessed where material.

The molecular standard operating procedure shall identify the primers and target regions, amplification conditions, library-preparation method, sequencing platform and chemistry, intended sequencing depth, sample randomization, negative controls, positive controls or mock communities, sequence-quality thresholds, contaminant-identification procedures, bioinformatic pipeline, taxonomic reference database, software versions, and data-retention arrangements.

Extraction blanks and amplification blanks shall be included in every applicable analytical batch. Positive controls or mock communities shall be used to evaluate amplification,

sequencing, taxonomic assignment, and batch consistency. Baseline and monitoring samples shall be randomized across extraction, amplification, and sequencing batches where feasible.

11.3.3 Molecular metrics

Microbial-community reporting shall include:

- (a) sample coverage and sequencing completeness;
- (b) observed or coverage-standardized Hill diversity of order $q=0$;
- (c) exponential Shannon diversity or Hill diversity of order $q=1$;
- (d) inverse Simpson diversity or Hill diversity of order $q=2$;
- (e) community composition;
- (f) beta diversity;
- (g) similarity or dissimilarity to an approved ecological reference;
- (h) temporal community turnover; and
- (i) indicator taxa, ecological guilds, or functional groups where their interpretation is supported by an approved and sufficiently reliable database.

Hill numbers shall be used as a coherent family of diversity measures, and comparisons among samples shall account for differences in sample coverage and completeness (Jost, 2006; Chao et al., 2014).

The Indicator Dictionary shall specify which of these metrics enter the MBS. Several mathematically related diversity metrics shall not receive duplicative weight. At least one community-composition or ecological-reference metric shall be included so that the microbial score is not based solely on alpha diversity.

Raw sequencing-read count or library size shall be treated as a technical QA/QC variable and shall not constitute a biodiversity indicator. Relative read abundance shall not be reported as absolute organism abundance.

Where absolute abundance is material to the theory of change, the initiative holder shall apply qPCR, digital PCR, internal quantitative standards, direct cell counts, phospholipid fatty-acid analysis, or another validated quantitative method. The selected method and reporting unit shall remain comparable throughout the quantification period.

Where qPCR is used to estimate the abundance of selected microbial gene sequences, the analytical procedure shall follow ISO 17601 or an equivalent validated method.

Compositional transformations and ecological-distance metrics shall be selected according to the data structure and shall be pre-specified in the statistical analysis plan. The analysis shall document the treatment of rare taxa, zero values, contaminants, batch effects, sequencing depth, and multiple comparisons.

11.3.4 Deliberately introduced microorganisms

Where microbial inoculants, mycorrhizal products, or other deliberately introduced organisms are used, sequences or measurements attributable to those organisms shall be identified where technically feasible.

The detection, abundance, or sequence reads of an introduced organism shall not, by themselves, constitute an increase in soil biodiversity. The initiative holder shall assess the wider response of the resident microbial community and shall demonstrate that the introduced organism has not displaced native organisms, increased ecological risk, or artificially inflated the MBS.

The initiative holder shall report the effect of including and excluding deliberately introduced organisms from the applicable calculations. The more conservative result shall be used unless BioCarbon approves another treatment.

11.4 Soil-fauna methods

The selected soil-fauna module or modules shall be sampled using standardized field units, extraction effort, preservation conditions, identification procedures, and reporting units appropriate to the target group. Molecular detection of fauna shall not replace direct faunal sampling unless equivalence has been demonstrated through a validated comparison and approved by BioCarbon.

11.4.1 Nematodes

Where nematodes are selected, sampling, extraction, and identification shall follow ISO 23611-4 or an equivalent validated procedure.

The assessment shall include, as applicable:

- (a) total abundance;
- (b) taxonomic richness or operational diversity;
- (c) bacterivorous, fungivorous, plant-feeding, omnivorous, and predatory guilds;
- (d) maturity, enrichment, structure, and channel indices;
- (e) community composition;
- (f) presence of harmful, beneficial, sensitive, or opportunistic groups; and
- (g) response to the pressures identified in the theory of change.

11.4.2 Microarthropods

Where microarthropods are selected, sampling and extraction shall follow ISO 23611-2 or an equivalent validated procedure.

Reported metrics shall include abundance, taxonomic or operational diversity, major taxonomic groups, ecological or functional groups, and community composition. Sampling area or volume, extraction duration, mesh size, temperature regime, preservation method, and identification resolution shall be documented.

11.4.3 Earthworms

Where earthworms are selected, sampling shall follow ISO 23611-1 or an equivalent validated procedure.

Reported metrics shall include density, biomass, taxonomic diversity, ecological groups, life stages, and community composition. Sampling area, extraction depth, extraction method, biomass condition, and treatment of juveniles shall be documented.

11.4.4 Macrofauna

Where macrofauna are selected, sampling shall follow ISO 23611-5, the Tropical Soil Biology and Fertility soil-monolith and hand-sorting method described by Ruiz, Lavelle and Jiménez (2008), or another validated method appropriate to the region and target groups.

Where the TSBF method is used, the initiative holder shall document the dimensions and depth of the soil monoliths, depth intervals, number and spatial arrangement of sampling units, hand-sorting effort, preservation conditions, taxonomic resolution, biomass procedure, and conversion of results to area-based units.

Reported metrics shall include density, biomass, taxonomic or operational diversity, community composition, and ecologically relevant functional groups. Pitfall traps may be used as a complementary measure of surface activity-density but shall not be used as the sole method for estimating soil-macrofauna density.

11.4.5 Faunal comparability

The same sampling area or volume, extraction effort, identification resolution, taxonomic authority, preservation method, reporting unit, and treatment of juvenile, damaged, or unidentified specimens shall be maintained across baseline and monitoring periods.

Where taxonomic identification capacity changes during the initiative, the initiative holder shall harmonize the datasets to the highest common taxonomic resolution or demonstrate comparability through an approved bridging procedure.

11.5 Biological function and biomass indicators

Biological-function and biomass indicators shall be used to interpret the condition and response of the direct biological communities. They shall not form part of the MBS, FBS, or SBI.

At minimum, the initiative shall measure:

- (a) microbial biomass carbon; and
- (b) basal soil respiration.

The initiative holder shall also select at least one additional biological-function indicator relevant to the theory of change, such as:

- (a) standardized decomposition rate;
- (b) β -glucosidase activity;
- (c) arylsulfatase activity;
- (d) phosphatase activity;
- (e) N-acetyl- β -glucosaminidase activity;
- (f) potential nitrification or another nitrogen-cycle process;
- (g) substrate-induced respiration;
- (h) metabolic quotient; or
- (i) another validated soil-biological function.

Microbial biomass carbon shall be determined using ISO 14240-2 or an equivalent validated method. Soil respiration shall be determined using ISO 16072 or an equivalent validated method. Soil enzyme activities shall be determined using ISO 20130, the FAO/GLOSOLAN-NETSOB Standard operating procedure for soil enzyme activities (de Carvalho Mendes, 2025), or another validated method that provides equivalent or better analytical performance.

The BioAS procedure may be used for the determination and interpretation of β -glucosidase and arylsulfatase activities where its documented domain of validity applies (Mendes et al., 2021). Where BioAS is used, the initiative holder shall document the applicable soil type, land use, sampling depth, sampling window, analytical procedure, reference values, and known limitations. BioAS reference values or interpretive classes shall not be transferred to another ecological, soil, land-use, or analytical context without documented validation.

Enzyme activity, respiration, or microbial biomass may respond to substrate availability, stress, temperature, moisture, or management without representing greater biodiversity. These variables shall therefore support ecological interpretation and no-harm assessment but shall not independently justify BioCredit issuance.

11.6 Soil habitat and physicochemical variables

The following variables shall be measured at baseline and during each full biological monitoring period:

- (a) soil texture;
- (b) gravimetric or volumetric moisture;
- (c) bulk density;
- (d) pH;
- (e) electrical conductivity where salinity risk is relevant;
- (f) soil organic carbon;
- (g) total nitrogen;
- (h) plant-available phosphorus;
- (i) temperature at sampling; and
- (j) sampling depth and horizon.

The initiative holder shall also measure, where relevant to the theory of change, reference domain, or risk assessment:

- (a) cation-exchange capacity;
- (b) aggregate stability;
- (c) penetration resistance;
- (d) infiltration;
- (e) porosity;
- (f) water-holding capacity;
- (g) redox potential;
- (h) contaminant concentrations;
- (i) exchangeable acidity;
- (j) base saturation;
- (k) pesticide residues; or
- (l) another variable necessary to interpret biological response.

Physicochemical variables shall not be weighted directly in the MBS, FBS, or SBI. Soil organic carbon shall not serve as a multiplier of the BioCredit quantity.

11.7 Pressure and management indicators

The initiative holder shall monitor the management practices and pressures identified in the baseline and theory of change. The selected variables shall be sufficient to demonstrate implementation, assess causal plausibility, detect displacement of pressures, and identify adverse effects.

The monitoring shall include, as applicable:

- (a) tillage type, depth, frequency, and disturbed area;
- (b) duration and percentage of soil cover;
- (c) crop, plant, and root diversity;
- (d) crop rotation and intercropping characteristics;
- (e) residue retention, removal, or burning;
- (f) fertilizer type, rate, timing, and placement;
- (g) pesticide active ingredient, rate, frequency, toxicity, persistence, and ecological-risk classification;
- (h) grazing density, duration, recovery period, and ground cover;
- (i) irrigation and drainage;
- (j) machinery traffic and compaction;
- (k) erosion and soil loss;
- (l) organic-amendment quantity, composition, quality, and date of application;
- (m) biological inputs and inoculants;
- (n) fire;
- (o) contamination events; and

(p) implementation and maintenance dates.

A change in a management or pressure variable may support causal attribution but shall not substitute for a measured response in the direct biological indicators.

11.8 Landscape and climatic variables

The initiative holder shall record the climatic, hydrological, topographic, and landscape variables required to interpret variation in soil biodiversity and distinguish initiative effects from external drivers.

These variables shall include, as applicable:

- (a) precipitation;
- (b) air and soil temperature;
- (c) drought, flooding, or soil-moisture anomalies;
- (d) elevation, slope, and topographic position;
- (e) land cover and vegetation condition;
- (f) field size and edge density;
- (g) proximity to natural or semi-natural habitat;
- (h) habitat connectivity;
- (i) hydrological condition; and
- (j) major climatic or disturbance events.

Remote-sensing and GIS variables may support land-cover monitoring, spatial stratification, implementation evidence, landscape analysis, and the identification of external disturbances. They shall not replace direct soil-biological measurements and shall not enter the SBI unless a separately validated and BioCarbon-approved direct relationship with the target biological attribute has been established.

11.9 Reference domains and indicator scoring

Each direct biological indicator included in the SBI shall be transformed to a score from 0 to 100 using a scoring function and reference domain established before baseline analysis.

$$s_{i,ht} = 100 \times f_i(X_{i,h,t} | R_{i,h}) \quad \text{Equation 1}$$

Where:

- $s_{i,ht}$ = standardized score for indicator i , stratum h , and time t ;
- $X_{i,h,t}$ = measured value of indicator i ;
- $R_{i,h}$ = documented reference domain applicable to indicator i and stratum h ; and
- f_i = pre-specified scoring function returning a value between 0 and 1.

The reference domain shall represent the ecological and analytical conditions within which the scoring function is valid. It shall be defined using the soil group, climate or ecological zone, land use, vegetation, management context, sampling depth, temporal window, taxonomic resolution, and analytical method relevant to the indicator.

Reference-domain benchmarks may be derived from suitable ecological reference areas, validated regional or national datasets, peer-reviewed evidence, recognized monitoring networks, or a documented combination of these sources. Where adequate independent reference information is unavailable, the initiative holder shall use the best available information, including pilot data and conservative ecological benchmarks, to define a provisional reference domain.

The initiative holder shall document and report the data sources, sampling and analytical conditions, assumptions, limitations, uncertainty, domain of validity, and scientific rationale supporting the selected benchmarks in the Indicator Dictionary and the applicable initiative documentation. Pilot data shall not be used as the sole basis for defining scoring limits unless their representativeness, analytical quality, and ecological relevance have been demonstrated. The provisional reference domain shall be reviewed and, where necessary, updated when sufficient independent information becomes available. Any update shall be documented, justified, and applied consistently to the baseline and monitored conditions.

Initiative-specific minimum and maximum observed values shall not be used retrospectively as scoring limits. The scoring function shall not be modified after inspection of monitoring results for the purpose of increasing the SBI or BioCredit quantity.

The same reference domain, scoring function, transformations, taxonomic resolution, and weights shall be applied to the monitored and baseline conditions. Values calculated using non-comparable methods or scoring architectures shall not be subtracted from one another under Section 12.

The operator $\text{clip}(z, 0, 1)$ used below limits the value z to the interval from 0 to 1.

The reference-domain protocol and its supporting information shall be included in the initiative documentation and made available for independent audit.

11.9.1 Positive monotonic response

Where higher indicator values represent better ecological condition, the score shall be:

$$s_{i,h,t} = 100 \times \text{clip}\left(\frac{x_{i,h,t} - L_{i,h}}{T_{i,h} - L_{i,h}}, 0, 1\right) \quad \text{Equation 2}$$

Where:

$s_{i,h,t}$ = standardized indicator score

- $x_{i,h,t}$ = measured indicator value
 $L_{i,h}$ = lower ecological benchmark corresponding to a score of zero; and
 $T_{i,h}$ = target or reference benchmark corresponding to a score of 100.

A positive monotonic function shall be used only where scientific evidence supports the interpretation that higher values represent better ecological condition throughout the applicable range.

11.9.2 Negative monotonic response

Where lower indicator values represent better ecological condition, the score shall be:

$$s_{i,h,t} = 100 \times clip\left(\frac{U_{i,h} - x_{i,h,t}}{U_{i,h} - T_{i,h}}, 0, 1\right) \quad \text{Equation 3}$$

Where $T_{i,h}$ represents the target upper benchmark corresponding to a score of 100; and

$U_{i,h}$ represents the unacceptable upper benchmark corresponding to a score of zero.

This function may be applied to indicators of ecological pressure, harmful organisms, or another condition where lower values are demonstrably preferable. Pressure variables shall not enter the SBI unless they are direct biological attributes included in the approved indicator architecture.

11.9.3 Optimum-range response

Where an indicator has an ecological optimum rather than a monotonic response, the score shall be calculated as:

$$s_{i,h,t} = \begin{cases} 0, & X_{i,h,t} \leq L_{i,h}^0 \\ 100 \left(\frac{X_{i,h,t} - L_{i,h}^0}{L_{i,h}^* - L_{i,h}^0} \right), & L_{i,h}^0 < X_{i,h,t} < L_{i,h}^* \\ 100, & L_{i,h}^* \leq X_{i,h,t} \leq U_{i,h}^* \\ 100 \left(\frac{U_{i,h}^0 - X_{i,h,t}}{U_{i,h}^0 - U_{i,h}^*} \right), & U_{i,h}^* < X_{i,h,t} < U_{i,h}^0 \\ 0, & X_{i,h,t} \geq U_{i,h}^0 \end{cases} \quad \text{Equation 4}$$

Where:

- $L_{i,h}^*, U_{i,h}^*$ = approved optimum interval; and
 $L_{i,h}^0$ and $U_{i,h}^0$ = lower and upper benchmarks corresponding to a score of zero.

The benchmarks and ecological basis for the optimum range shall be documented in the Indicator Dictionary.

11.9.4 Community-composition response

A community-composition score may be calculated as:

$$s_{i,h,t} = 100 \times \text{clip} \left(1 - \frac{d_{i,h,t}}{d_{i,h}^0}, 0, 1 \right) \quad \text{Equation 5}$$

Where:

$d_{i,h,t}$ = approved ecological distance from the reference or target community; and
 $d_{i,h}^0$ = pre-specified distance corresponding to a score of zero.

The distance metric, abundance transformation, taxonomic resolution, treatment of rare taxa, reference-community construction, and zero-score benchmark shall be defined before baseline analysis.

Higher richness or activity shall not automatically be interpreted as better condition where the response is driven by opportunistic, invasive, pathogenic, disturbance-tolerant, or deliberately introduced organisms. In such cases, an optimum-range, composition-based, or negative-response function shall be used.

11.10 Microbial Biodiversity Score

For each stratum h and time t, the Microbial Biodiversity Score shall be calculated as the weighted geometric mean of the approved microbial indicator scores:

$$MBS_{h,t} = 100 \prod_{i=1}^{n_M} \left(\frac{s_{i,h,t}}{100} \right)^{w_i} \quad \text{Equation 6}$$

Where:

$MBS_{h,t}$ = Microbial Biodiversity Score;
 $s_{i,h,t}$ = approved microbial indicator score;
 w_i = approved weight of microbial indicator i, and
 $\sum_{i=1}^{n_M} w_i = 1$

Unless an alternative weighting scheme is approved before baseline analysis, bacterial and archaeal indicators shall receive a combined weight of 0.5 and fungal indicators shall receive a combined weight of 0.5.

Within each microbial component, weights shall be assigned so that related Hill numbers, composition metrics, and derived indices do not receive duplicative emphasis. Additional quantitative microbial indicators shall be nested within the applicable microbial component and shall not increase its total weight unless BioCarbon approves a revised architecture for the reference domain.

11.11 Faunal Biodiversity Score

For each stratum h and time t , the Faunal Biodiversity Score shall be calculated as:

$$FBS_{h,t} = 100 \prod_{j=1}^{n_F} \left(\frac{S_{j,h,t}}{100} \right)^{v_j} \quad \text{Equation 7}$$

Where:

$$\begin{aligned} FBS_{h,t} &= \text{Faunal Biodiversity Score;} \\ S_{j,h,t} &= \text{approved faunal indicator or module score;} \\ v_j &= \text{approved weight of faunal indicator or module } j; \text{ and} \\ \sum_{j=1}^{n_F} v_j &= 1 \end{aligned}$$

Where one faunal module is approved for the applicable ecological context, its total weight shall equal 1. Where two or more faunal modules are required, their weights shall sum to 1 and shall be established before baseline analysis.

No faunal group shall receive a fixed default weight unless it is a mandatory component of the applicable reference-domain protocol. Equal module weights shall apply by default where more than one faunal module is used, unless an alternative evidence-based weighting scheme is approved before baseline analysis.

The same faunal modules, indicators, methods, taxonomic resolution, weights, and aggregation procedures shall be applied to the monitored and baseline conditions

11.12 Soil Biodiversity Index

The Soil Biodiversity Index represents the condition of the approved direct microbial and soil-fauna dimensions within stratum h at time t . It shall be calculated as:

$$SBI_{h,t} = 100 \left(\frac{MBS_{h,t}}{100} \right)^{w_M} \left(\frac{FBS_{h,t}}{100} \right)^{w_F} \quad \text{Equation 8}$$

Where:

$SBI_{h,t}$ = Soil Biodiversity Index;
 W_M = approved weight of the microbial dimension;
 W_F = approved weight of the faunal dimension; and
 $W_M + W_F = 1$

Unless another weighting scheme has been approved for the applicable reference domain before baseline analysis:

$$W_M = 0.5$$

and

$$W_F = 0.5$$

The equal weights specified above are applied as a default methodological convention where the applicable reference-domain protocol does not provide a sufficiently robust empirical or theoretical basis for assigning differential weights. Equal weighting shall not be interpreted as evidence that the represented taxa, biological groups, modules, or dimensions have equal ecological importance or are ecologically equivalent. Under geometric aggregation, the weights define the formal trade-offs among components within the composite index rather than direct measures of ecological importance.

The selected weighting and aggregation procedures shall be documented, and their influence on the MBS, FBS, and SBI shall be evaluated through uncertainty and sensitivity analysis during technical validation of the index and periodic methodological review. Alternative weights may be applied only where they are supported by a clear conceptual rationale and relevant empirical evidence and are established before baseline analysis (OECD and European Commission, Joint Research Centre, 2008).

The SBI shall range from 0 to 100. The geometric mean shall limit compensation between the microbial and faunal dimensions. As a mathematical consequence, a low score in either dimension exerts a stronger influence on the SBI than it would under an arithmetic mean, and a score of zero in either dimension results in an SBI of zero. This behavior reflects a methodological assumption that both dimensions are necessary components of soil biodiversity condition; it shall not be interpreted as an empirically established or universally applicable ecological relationship.

A score of zero shall be assigned only where the applicable reference-domain scoring function places the observed value at or beyond the approved zero-score benchmark. Missing data, analytical failure, insufficient sampling, or the use of a biological module that is unsuitable for the applicable ecological context shall not be represented by a score of zero. Such conditions shall be addressed through the data-quality, missing-data, and eligibility requirements of this methodology.

The equations established in this section shall be applied separately to calculate the monitored values $MBS_{h,t}^I$, $FBS_{h,t}^I$, and $SBI_{h,t}^I$, and the corresponding baseline values $MBS_{h,t}^{BL}$, $FBS_{h,t}^{BL}$, and $SBI_{h,t}^{BL}$.

Section 12 determines the BioCredits associated with verified soil biodiversity conservation outcomes using the conservative monitored SBI, the applicable outcome pathway, the eligible area, and the required integrity, uncertainty, leakage, and reversal adjustments. The SBI shall be interpreted as an index of soil biodiversity condition for the approved direct microbial and soil-fauna dimensions. It shall not be interpreted as a universal ecological constant, a percentage of total biodiversity, or an automatic entitlement to BioCredit issuance.

Uncertainty in the indicator scores, MBS, FBS, and SBI shall be estimated and propagated in accordance with Appendix C. Where bootstrap, Monte Carlo, Bayesian, or another simulation-based procedure is used, the complete scoring and aggregation chain shall be recalculated within every iteration.

11.13 Supporting variables

Biological-function, biomass, physicochemical, management, pressure, climatic, hydrological, and landscape variables shall be reported as supporting variables.

Supporting variables shall be used to:

- (a) evaluate the plausibility of the causal pathway;
- (b) identify confounding factors and external drivers;
- (c) interpret direct biological responses;
- (d) assess potential adverse effects;
- (e) evaluate consistency with the theory of change;
- (f) support leakage and risk assessment; and
- (g) inform adaptive management.

Co-occurrence ecological network metrics, including network connectivity, modularity, nestedness, centrality, or average path length, may be reported as optional supporting variables where they are scientifically justified, reproducible, and relevant to the theory of change. Such metrics shall support interpretation of ecosystem resilience or structural recovery but shall not enter the MBS, FBS, or SBI unless BioCarbon has approved a specific direct biological indicator protocol for that purpose.

Supporting variables shall not be added to the MBS, FBS, or SBI. They shall not independently generate BioCredits or act as multipliers of the BioCredit quantity.

Where supporting variables indicate material degradation, contamination, increased ecological pressure, or another condition inconsistent with the claimed biodiversity conservation outcome, the affected stratum shall be assessed under Section 11.14 and the applicable risk and corrective-action requirements.

11.14 Non-compensation and no-material-decline requirements

A positive difference in the overall SBI shall not compensate for a material decline in either direct biodiversity dimension or in a critical direct biological indicator identified in the Indicator Dictionary.

For each direct dimension d , the difference between the monitored and baseline conditions shall be:

$$\Delta D_{d,h,t} = D_{d,h,t}^I - D_{d,h,t}^{BL} \quad \text{Equation 9}$$

Where:

- D = either the MBS or FBS;
- $D_{d,h,t}^I$ = monitored dimension score; and
- $D_{d,h,t}^{BL}$ = dimension score expected under the applicable baseline scenario.

The no-material-decline criterion shall be:

$$LCB_{90}(\Delta D_{d,h,t}) \geq -\delta_{d,h} \quad \text{Equation 10}$$

Where:

- LCB_{90} = one-sided 90% lower confidence bound;
- $\Delta D_{d,h,t}$ = difference between the monitored and baseline scores for direct biodiversity dimension d , stratum h , and monitoring period t ; and
- $\delta_{d,h}$ = pre-specified ecological materiality threshold for direct biodiversity dimension d within the applicable reference domain.

The applicable values of $\delta_{d,h}$ shall be specified in the Indicator Dictionary and approved before baseline analysis. A direct biodiversity dimension for which no applicable threshold has been established shall not be used for positive BioCredit quantification.

Where the BBS or another applicable BioCarbon normative document requires a more conservative confidence level, the more stringent requirement shall apply.

A comparable no-material-decline rule shall be established for any critical direct biological indicator whose deterioration could be concealed by aggregation within the MBS or FBS.

A stratum shall not proceed to positive BioCredit quantification where:

- (a) either direct biodiversity dimension fails the no-material-decline criterion;
- (b) a critical direct biological indicator exceeds its approved adverse-change threshold;
- (c) a required direct biological module or indicator has been omitted without prior approval;
- (d) the method, reference domain, scoring function, or indicator set is not comparable between the monitored and baseline conditions;
- (e) invasive, pathogenic, harmful, or deliberately introduced organisms have caused a material artificial increase in a direct score;
- (f) contamination, ecotoxicological risk, erosion, compaction, salinization, or another relevant pressure has increased materially;
- (g) supporting variables indicate material degradation inconsistent with the claimed biodiversity conservation outcome; or
- (h) applicable BBS safeguards or other eligibility requirements have not been fulfilled.

The pathway-specific eligibility conditions, conservative monitored SBI, ecological materiality requirements, and non-compensation rules established under Section 12 shall be applied separately for each stratum and monitoring period.

12 Quantification of BioCredits

BioCredits quantified under this methodology shall represent verified soil biodiversity conservation outcomes demonstrated for a defined monitoring period, in accordance with the applicable outcome pathway, the approved baseline or counterfactual, the direct biological indicators, and the requirements of the BBS.

BioCredits shall not be issued merely because an individual indicator, supporting variable, or management practice changes in a favorable direction. The Initiative holder shall first demonstrate that an eligible soil biodiversity conservation outcome has occurred through enhancement or recovery, avoided loss, or maintenance, and that the outcome is additional, attributable, measurable, verifiable, conservatively quantified, and supported by direct biological evidence.

Soil organic carbon, enzyme activity, microbial biomass, vegetation cover, agricultural productivity, management practices, or other supporting variables shall not independently generate BioCredits and shall not be used as multipliers of the BioCredit quantity.

12.1 Quantification unit

For calculation purposes, one BioCredit shall correspond to one verified SBI point-hectare associated with an eligible soil biodiversity conservation outcome demonstrated for the applicable monitoring period.

The SBI point-hectare is an accounting unit used to express the quantity of verified soil biodiversity conservation outcomes under this methodology. It does not represent a universal

ecological constant, does not imply equivalence among different soils, agroecosystems, biological communities, or reference domains, and shall not be interpreted independently from the approved outcome pathway, baseline or counterfactual, monitoring period, eligible area, and conformity determination.

The BioCredit quantity shall be calculated only where the applicable pathway-specific eligibility condition is met. Where the eligibility condition is not met, the BioCredit quantity for the corresponding stratum and monitoring period shall be zero.

Each BioCredit submitted for issuance shall be associated with:

- (a) the initiative and initiative holder;
- (b) the applicable stratum or spatial accounting unit;
- (c) the geographic location and eligible area;
- (d) the conservation activity category;
- (e) the applicable outcome pathway;
- (f) the monitoring period;
- (g) the applicable baseline scenario;
- (h) the methodology version;
- (i) the approved indicator set and reference domain;
- (j) the uncertainty, materiality, and leakage treatment applied; and
- (k) the corresponding audit, conformity determination, issuance, and Registry records, once issued.

12.2 Soil biodiversity conservation outcome

The soil biodiversity conservation outcome shall be determined for each stratum h and monitoring period t according to the applicable outcome pathway.

For enhancement or recovery, the Initiative holder shall demonstrate that the monitored soil biodiversity condition reflects a measurable and attributable recovery or improvement relative to the applicable baseline or counterfactual.

For avoided loss, the Initiative holder shall demonstrate that the monitored soil biodiversity condition is maintained above the condition expected under a credible declining baseline or counterfactual.

For maintenance, the Initiative holder shall demonstrate that the monitored soil biodiversity condition remains within the approved conservation condition or reference domain and that continued conservation action, stewardship, management, protection, governance, or financing was necessary to sustain that condition.

For each stratum h and monitoring period t , the gross BioCredit quantity shall be calculated as:

$$BC_{gross,h,t} = A_{h,t} \times SBI_{cons,h,t} \times Felig_{h,t} \quad \text{Equation 11}$$

Where:

- $BC_{gross,h,t}$ = gross BioCredits for stratum h and monitoring period t;
- $A_{h,t}$ = eligible area of stratum h during monitoring period t, in hectares;
- $SBI_{cons,h,t}$ = conservative monitored Soil Biodiversity Index for stratum h and monitoring period t, after uncertainty treatment; and
- $Felig_{h,t}$ = pathway eligibility factor, equal to 1 where the applicable outcome pathway has been demonstrated and all eligibility conditions are met, and equal to 0 where such conditions are not met.

The use of $Felig_{h,t}$ ensures that BioCredits are not generated from soil biodiversity condition alone. BioCredits shall be quantified only where the monitored condition corresponds to an eligible, additional, attributable, and verified soil biodiversity conservation outcome under the applicable pathway.

Only areas represented by the approved sampling and monitoring design shall be included. Excluded, unmonitored, non-compliant, or insufficiently represented areas shall not contribute to the BioCredit quantity.

12.3 Conservative quantification and materiality

Uncertainty shall be quantified and propagated in accordance with Appendix C. For each stratum h and monitoring period t, the conservative monitored Soil Biodiversity Index shall be calculated using the lower one-sided 90% confidence bound of the monitored SBI distribution, unless the BBS or another applicable BioCarbon normative document requires a more conservative treatment.

For simulation-based uncertainty analysis, the conservative monitored SBI for stratum h and monitoring period t shall be calculated as:

$$SBI_{cons,h,t} = Q_{0.10}(SBI_{h,t}^{(1)}, SBI_{h,t}^{(2)}, \dots, SBI_{h,t}^{(B)}) \quad \text{Equation 12}$$

Where:

- $SBI_{cons,h,t}$ = conservative monitored Soil Biodiversity Index for stratum h and monitoring period t;
- $Q_{0.10}(\cdot)$ = 10th-percentile operator, corresponding to a one-sided 90% lower confidence bound;

$SBI_{h,t}^{(b)}$ = monitored Soil Biodiversity Index calculated in bootstrap, Monte Carlo, Bayesian posterior, or other valid simulation iteration b ; and
 B = total number of valid simulation iterations.

Where uncertainty is not implemented through simulation, $SBI_{cons,h,t}$ shall correspond to the one-sided 90% lower confidence bound of the monitored SBI estimate.

For enhancement or recovery, the Initiative holder shall demonstrate that the monitored soil biodiversity condition reflects a measurable and attributable recovery or improvement relative to the applicable baseline or counterfactual, and that such recovery or improvement is ecologically material within the approved reference domain.

For avoided loss, the Initiative holder shall demonstrate that the monitored soil biodiversity condition is maintained above the condition expected under a credible declining baseline or counterfactual, and that the avoided deterioration is ecologically material within the approved reference domain.

For maintenance, the Initiative holder shall demonstrate that the monitored soil biodiversity condition remains within the approved conservation condition or reference domain, and that continued conservation action, stewardship, management, protection, governance, or financing was necessary to sustain that condition relative to the applicable baseline or counterfactual.

The pathway eligibility factor shall be assigned as follows:

$$F_{elig,ht} = \begin{cases} 1, & \text{where the applicable pathway – specific eligibility condition has been demonstrated} \\ 0, & \text{where the applicable pathway – specific eligibility condition has not been demonstrated} \end{cases}$$

Where:

$F_{elig,h,t}$ = pathway eligibility factor for stratum h and monitoring period t

Ecological materiality thresholds shall be used to determine pathway eligibility and to avoid crediting trivial or non-meaningful changes. They shall not be treated as an additional BioCredit quantity or as an automatic deduction from the monitored SBI.

A fixed percentage deduction shall not replace quantitative uncertainty analysis where the available data support direct estimation. Uncertainty shall not be deducted more than once.

12.4 Successive monitoring periods and prevention of repeated issuance

BioCredits may be quantified for successive, non-overlapping monitoring periods where eligible soil biodiversity conservation outcomes are independently demonstrated, quantified, audited, and approved for each respective monitoring period.

The issuance of BioCredits for one monitoring period shall not preclude issuance for a subsequent monitoring period in the same geographic area, provided that the subsequent issuance relates to conservation performance attributable to the subsequent monitoring period and does not represent the same outcome for the same temporal and spatial scope.

For avoidance of doubt, this section does not establish progressive issuance, ramp-up crediting, staged issuance, or partial recognition of outcomes based on maturity percentages. It establishes only the rules for temporal attribution and prevention of repeated issuance of the same soil biodiversity conservation outcome.

12.5 Leakage and other applicable deductions

Material displacement of pressures outside the initiative boundary shall be assessed in accordance with Section 14 and the BBS. Where leakage is identified and can be quantified, the corresponding soil biodiversity impact shall be converted into SBI point-hectares and deducted from the gross BioCredit quantity.

The BioCredit quantity submitted for issuance shall be:

$$BC_t^{net} = \max \left[0, \sum_{h=1}^H BC_{h,t}^{gross} - L_t - D_t \right] \quad \text{Equation 13}$$

Where:

- BC_t^{net} = BioCredit quantity proposed for issuance for monitoring period t;
- L_t = quantified leakage deduction, expressed in SBI point-hectares; and
- D_t = any other deduction expressly required by the BBS or another binding BioCarbon normative document.

Where leakage is estimated as a proportion of the gross outcome:

$$L_t = \lambda_t \sum_{h=1}^H BC_{h,t}^{gross} \quad \text{Equation 14}$$

Where λ_t is the conservatively estimated leakage proportion between 0 and 1.

Where leakage cannot be quantified reliably but available evidence indicates that it is material, a conservative deduction approved by BioCarbon shall be applied. Significant unmitigated leakage may make the affected outcome ineligible for issuance.

No automatic buffer, risk-reserve, or non-tradable reserve deduction shall be applied unless such a mechanism is expressly established by the BBS or another binding BioCarbon normative document. Reversals detected after issuance shall be addressed under Section 14 and the

applicable BBS procedures and shall not be represented as an automatic prospective deduction in Equation 13.

12.6 Aggregation and non-compensation

BioCredit quantities may be aggregated across strata for an issuance batch only after each stratum has independently demonstrated:

- (a) the applicable pathway-specific eligibility condition has been demonstrated and $F_{elig_{h,t}} = 1$;
- (b) the outcome satisfies the applicable ecological materiality requirements;
- (c) compliance with the non-compensation and no-material-decline requirements of Section 11.14;
- (d) adequate data quality and uncertainty treatment;
- (e) compliance with applicable safeguards;
- (f) completion of the leakage assessment; and
- (g) compliance with the applicable monitoring and audit requirements.

A negative or ineligible result in one stratum shall not be compensated by a positive result in another stratum. The affected stratum shall be assigned zero BioCredits and shall be evaluated for adverse effects, corrective action, or reversal, as applicable.

Aggregation shall preserve traceability to the underlying strata, sampling units, reference domains, monitoring results, and conservation activities. Preservation, ecological restoration, and sustainable-use activities may contribute to the same BioCredit issuance architecture, but the applicable activity category shall remain identifiable as an attribute of the corresponding outcome.

12.7 Rounding

The final BioCredit quantity shall be rounded down to the precision permitted by the BioCarbon Registry. Upward rounding shall not be permitted.

Rounding shall occur only after all uncertainty, materiality, pathway-specific eligibility conditions, leakage, and other applicable deductions have been applied.

12.8 Ex-post issuance

All quantities calculated before BioCarbon's conformity determination shall be treated as proposed BioCredit quantities and shall not constitute issued BioCredits.

BioCredits may be issued only after:

- (a) completion of the applicable monitoring period;
- (b) preparation of the Monitoring Report;
- (c) completion of internal QA/QC;
- (d) calculation of the SBI and the soil biodiversity conservation outcome;

- (e) application of uncertainty, materiality, leakage, and all other applicable deductions;
- (f) independent audit by an accredited and BioCarbon-approved CAB;
- (g) BioCarbon's conformity determination and issuance of the corresponding Conformity Statement;
- (h) fulfillment of the applicable transparency and disclosure requirements; and
- (i) issuance of the BioCredits Issuance Statement by BioCarbon.

Indicative BioCredit potential estimates, forward-looking calculations, activity records, advance-purchase agreements, or projected outcomes shall not be represented as issued BioCredits.

The number of BioCredits authorized by BioCarbon may differ from prior estimates or from the quantity initially submitted where such difference results from monitored data, audit findings, baseline consistency, uncertainty, leakage, reversals, safeguards, or another applicable BBS requirement.

12.9 Corrections

Where an error, omission, methodological inconsistency, data-quality failure, incorrect baseline treatment, omitted leakage source, or incorrect uncertainty calculation is identified, the initiative holder shall recalculate the affected soil biodiversity conservation outcome and BioCredit quantity.

The correction shall preserve the original data, calculation files, assumptions, and version history; identify the cause and magnitude of the error; apply the corrected method consistently to all affected strata and monitoring periods; and be submitted for review through the applicable audit and conformity-determination process.

Where an error is identified after BioCredit issuance, the initiative holder shall notify BioCarbon without delay. Any adjustment, suspension, correction, cancellation, replacement, or other Registry action shall be determined in accordance with the BBS and the applicable BioCarbon Program procedures.

12.10 Outcome integrity, claims, and double counting

BioCredits issued under this methodology may support biodiversity offsetting, environmental compensation, conservation investment, or voluntary biodiversity-market claims where permitted by the BBS and applicable law. Any such use shall be consistent with the verified soil biodiversity conservation outcome, the applicable baseline or counterfactual, the monitoring period, the retired BioCredits, Registry records, and BioCarbon requirements on attribution, claims, transparency, and prevention of double counting, double issuance, double use, and multiple attribution.

Where the same geographic area, activities, data, financing, or monitoring systems support other environmental units, including carbon, water, ecosystem-service, or other biodiversity units, the Initiative holder shall disclose the overlap and demonstrate that each unit represents

a distinct environmental outcome. The same soil biodiversity conservation outcome shall not be issued, used, attributed, or claimed more than once.

13 Monitoring plan

The Monitoring Plan shall provide the information required to verify implementation, quantify direct biodiversity, interpret biological change, detect harm or reversal, estimate uncertainty and support independent audit. Monitoring shall use the strata, sampling units, depths, methods and temporal windows established for the baseline, unless an approved comparability assessment supports a change.

The monitoring plan shall form part of the Conservation Initiative Document.

13.1 Monitoring objectives

The monitoring plan shall:

- (a) verify implementation of initiative activities;
- (b) monitor the relevant pressures and threats;
- (c) quantify direct microbial and faunal biodiversity;
- (d) monitor supporting biological functions and soil conditions;
- (e) detect material adverse changes;
- (f) distinguish initiative effects from natural and external variation;
- (g) update leakage and risk assessments;
- (h) identify reversals;
- (i) support uncertainty estimation; and
- (j) provide traceable evidence for BioCredit issuance.

13.2 Monitoring components

The monitoring plan shall include:

- (a) field monitoring;
- (b) laboratory and molecular analysis;
- (c) management and pressure monitoring;
- (d) climatic and hydrological monitoring;
- (e) spatial and remote-sensing monitoring, where relevant;
- (f) control-area monitoring;
- (g) leakage monitoring;
- (h) environmental and social safeguard monitoring;
- (i) data-quality monitoring; and
- (j) adaptive-management review.

13.3 Monitoring design and frequency

The Monitoring Plan shall include the minimum monitoring frequencies specified in Table 3.

Table 3. Monitoring minimum frequencies

Monitoring element	Minimum frequency
Implementation and management records	Continuously recorded and summarized at least annually
Land cover and major disturbance	At least annually
Relevant climatic and hydrological variables	Continuous, monthly, seasonal, or event-based, according to data availability and ecological relevance
Full microbial indicator panel	At baseline and each BioCredit issuance monitoring period
Full faunal indicator panel	At baseline and each BioCredit issuance monitoring period
Microbial biomass and basal respiration	At each full biological monitoring campaign
Selected additional biological function	At each full biological monitoring campaign
Soil habitat and physicochemical panel	At each full biological monitoring campaign
Pesticide, contaminant, salinity, or other risk variables	At a frequency determined by the identified risk and theory of change
Control areas	At the same frequency and within the same temporal window as the initiative area

The interval between full direct biological monitoring campaigns shall not exceed three years unless BioCarbon approves an indicator-specific longer interval based on demonstrated ecological stability and monitoring sensitivity.

No BioCredits shall be issued for a monitoring period that lacks current direct biological data. Where seasonal variability is material, the same seasonal or production-cycle windows used in the baseline shall be repeated. Initiative and control areas shall be sampled contemporaneously, and crop stage, soil moisture, recent precipitation, temperature, tillage, grazing, fertilization, pesticide application and other relevant events shall be recorded.

13.4 Monitoring locations

Monitoring shall use the approved baseline sampling units wherever feasible.

Permanent sampling units shall:

- (a) be accurately georeferenced;
- (b) have a unique identifier;
- (c) be marked physically where appropriate and permissible;
- (d) have sufficient spatial documentation to enable relocation;
- (e) remain independent field replicates; and

- (f) be protected from avoidable sampling disturbance.

Where a permanent unit becomes inaccessible or invalid, replacement shall follow Appendix B. Replacement shall not be selected on the basis of observed biodiversity condition.

13.5 Temporal comparability

Monitoring shall be conducted within the same defined seasonal, phenological, and management windows as the baseline.

The initiative holder shall record:

- (a) sampling date and time;
- (b) crop or vegetation stage;
- (c) soil moisture;
- (d) recent precipitation;
- (e) air and soil temperature;
- (f) irrigation or drainage conditions;
- (g) grazing status;
- (h) tillage and traffic events;
- (i) fertilizer and amendment application;
- (j) pesticide application;
- (k) fire or disturbance; and
- (l) other events capable of influencing the indicator.

Material temporal deviations shall be included as covariates, subjected to sensitivity analysis, or treated through a conservative adjustment.

13.6 Field sampling and sample handling

Field procedures shall follow Appendix B and the parameter-specific standard operating procedures.

The monitoring plan shall define:

- (a) sampling-unit dimensions;
- (b) number and location of subsamples;
- (c) compositing procedure;
- (d) sample mass or volume;
- (e) sampling depth and horizon;
- (f) equipment decontamination;
- (g) field blanks and duplicate samples;
- (h) sample labels;
- (i) preservation;
- (j) maximum holding time;
- (k) transport conditions;

- (l) chain of custody; and
- (m) archive-sample requirements.

Samples intended for different analytical purposes shall be divided, preserved, and transported according to the requirements of each analysis.

13.7 Molecular QA/QC

Each molecular-analysis batch shall include:

- (a) extraction blanks;
- (b) amplification blanks;
- (c) positive controls or mock communities;
- (d) technical controls necessary to evaluate batch performance;
- (e) documented sample randomization;
- (f) criteria for sequence retention and removal;
- (g) contaminant-screening procedures;
- (h) reporting of read loss at each processing stage; and
- (i) a record of all software, parameters, databases, and versions.

Where baseline and monitoring samples are processed in different batches, the initiative holder shall minimize batch effects and shall demonstrate comparability using common controls, retained samples, randomized processing, or another validated bridging procedure.

13.8 Laboratory QA/QC

Laboratory QA/QC shall include, as applicable:

- (a) calibration and maintenance records;
- (b) certified or internal reference materials;
- (c) reagent blanks;
- (d) laboratory duplicates;
- (e) control samples;
- (f) recovery tests;
- (g) detection and quantification limits;
- (h) precision and bias estimates;
- (i) control charts;
- (j) proficiency testing or interlaboratory comparison; and
- (k) corrective-action records.

13.9 Data validation and outliers

Outliers and anomalous values shall be assessed through a documented technical review. Values shall not be excluded solely because they exceed a fixed number of standard deviations from the mean. The review shall consider field notes, chain of custody, sampling conditions, laboratory QA/QC, molecular controls, batch effects, transcription errors, contamination,

ecological plausibility, and consistency with comparable observations. Exclusion of data shall be justified, documented, reproducible, and conservative. Both the original dataset and the dataset used for calculation shall be retained and made available for audit.

13.10 Missing data

Missing direct biological data shall not be replaced using simple mean substitution.

Imputation may be used for supporting variables only where:

- (a) the procedure was pre-specified;
- (b) the missingness mechanism has been evaluated;
- (c) uncertainty is propagated;
- (d) the imputation does not increase the credited outcome; and
- (e) the procedure is scientifically justified.

Where missing direct biological data prevent reliable estimation for a sampling unit, stratum, or monitoring period, the affected outcome shall be excluded or conservatively reduced.

13.11 Statistical monitoring analysis

Monitoring analysis shall:

- (a) follow the pre-specified statistical analysis plan;
- (b) use treatment, time, and treatment-by-time effects where applicable;
- (c) account for repeated measurements and hierarchical sampling;
- (d) account for spatial and temporal correlation;
- (e) use appropriate transformations or distributions;
- (f) use compositional methods for sequencing data where required;
- (g) evaluate multivariate community composition using methods appropriate to the data structure, ecological hypothesis, and approved sampling design;
- (h) quantify effect sizes and confidence intervals;
- (i) propagate uncertainty to SBI and BioCredit estimates; and
- (j) distinguish statistical significance from ecological materiality.

Permutational multivariate analysis of variance (PERMANOVA) may be used to evaluate differences in community composition associated with initiative condition, monitoring time, stratum, management, or their interactions, where appropriate to the theory of change and the approved statistical design (Anderson, 2001). The ecological-distance measure, data transformation, model terms, covariates, permutation scheme, and number of permutations shall be specified in the statistical analysis plan before the corresponding monitoring results are evaluated.

The permutation scheme shall reflect the structure of the sampling design. Permutations shall be restricted within blocks, matched pairs, permanent sampling units, strata, or other exchangeability units where required by repeated measurements, hierarchical sampling,

spatial structure, or the experimental design. For molecular-community data, the selected transformation and distance measure shall be consistent with the compositional-data requirements established in Section 11.3.3.

Homogeneity of multivariate dispersion shall be evaluated before a significant PERMANOVA result is interpreted as evidence of a difference in community composition. Where dispersion differs materially among the groups compared, the initiative holder shall determine and report whether the observed result is attributable to differences in multivariate centroids, dispersion, or both. A distance-based test of homogeneity of multivariate dispersions or another appropriate diagnostic procedure may be used for this purpose (Anderson, 2006).

PERMANOVA results shall report the distance measure and transformation applied, model formula, degrees of freedom, sums of squares, pseudo-F statistic, proportion of variation explained, permutation p-value, number and restriction of permutations, dispersion diagnostics, and any pairwise or post-hoc comparisons. Where multiple comparisons are conducted, the applicable adjustment procedure shall be reported.

The initiative holder shall report both the estimated change and its uncertainty.

13.12 Remote sensing and GIS monitoring

Remote sensing may be used to monitor:

- (a) land-cover change;
- (b) vegetation cover;
- (c) soil exposure;
- (d) crop or pasture phenology;
- (e) fire;
- (f) flooding or drought;
- (g) erosion risk;
- (h) habitat connectivity;
- (i) implementation extent; and
- (j) potential leakage.

Remote sensing shall not replace direct soil biological measurements.

Spatial datasets shall identify the sensor, product, acquisition date, resolution, processing level, classification procedure, accuracy assessment, and uncertainty.

13.13 Data management and traceability

The initiative holder shall maintain an integrated and auditable information system that links strata, sampling units, field samples, laboratory batches, molecular libraries, analytical results, spatial data, statistical code and BioCredit calculations through unique identifiers. Original data shall be retained together with a documented record of corrections and transformations. Molecular records shall include raw FASTQ or equivalent files, sample-to-library mapping,

feature and taxonomy tables, reference-database versions, controls and the scripts or parameter files required to reproduce the final metrics.

The system shall be technology-neutral. Open-source or proprietary software may be used provided that data, processing procedures and results remain accessible, traceable and reproducible. Non-confidential information required by the BBS shall be made available for audit and disclosure, while personal, commercially sensitive, culturally sensitive and community-governed data shall be protected in accordance with applicable rights, consent and Data Sovereignty requirements.

13.14 Monitoring Report

Each Monitoring Report shall include:

- (a) the monitoring period;
- (b) the applicable methodology version;
- (c) monitored strata and areas;
- (d) activities implemented;
- (e) deviations from the Conservation Initiative Document;
- (f) field and laboratory methods;
- (g) sample sizes and locations;
- (h) raw and processed indicator results;
- (i) QA/QC results;
- (j) SBI calculations;
- (k) supporting variables;
- (l) statistical analyses;
- (m) uncertainty assessment;
- (n) additionality status;
- (o) leakage assessment;
- (p) risk and reversal assessment;
- (q) safeguard monitoring;
- (r) adaptive and corrective measures;
- (s) gross and net BioCredit calculations;
- (t) limitations; and
- (u) evidence and dataset references.

Where applicable under the BBS, the Monitoring Report shall also include the status of the applicable outcome pathway, pathway-specific eligibility assessment, SDSs assessment, SDG contributions, stakeholder engagement, grievance mechanism, FPIC and Data Sovereignty requirements, climate change adaptation plan, BioCredit ownership and benefit-sharing arrangements, and any public-disclosure information required for conformity determination.

Such information shall support conformity determination under the BBS but shall not enter the SBI or independently generate BioCredits.

13.15 Adaptive action

Where monitoring identifies a material deviation from the approved theory of change, baseline assumptions, expected indicator trajectory, previously reported biodiversity conservation outcome, or applicable data-quality requirements, the initiative holder shall investigate and document the cause, determine the affected area and monitoring period, and implement corrective or adaptive measures proportionate to the nature, extent, severity, and duration of the deviation. The affected outcome shall not be submitted for BioCredit issuance where the deviation prevents reliable quantification, indicates a material decline or potential reversal, or remains unresolved at the time of reporting. The measures implemented and evidence of their effectiveness shall be documented in the Monitoring Report and assessed during subsequent monitoring periods; an extraordinary audit shall be requested where required under the BBS.

14 Durability and risk management of soil biodiversity conservation outcomes

The initiative holder shall manage risks affecting the durability of soil biodiversity conservation outcomes, including leakage and reversal risks, in accordance with the BBS and applicable BioCarbon requirements.

14.1 Durability

The Initiative holder shall define the period for which the claimed soil biodiversity outcome is expected to be maintained.

The Initiative holder shall demonstrate that the claimed durability period is supported by legal or customary authority, technical capacity, adequate staffing and institutional arrangements, financial sustainability, access to monitoring resources, maintenance of required infrastructure or management systems, stakeholder support and governance arrangements, and a response plan for foreseeable disturbances.

Where continued management is necessary to maintain the biodiversity outcome, the outcome shall not be described as self-sustaining unless evidence supports that conclusion.

14.2 Risk assessment

The Initiative holder shall identify, evaluate, and manage material risks that could affect the durability, attribution, or integrity of the claimed soil biodiversity conservation outcome. The assessment shall consider site-specific ecological, climatic, management, legal, social, financial, institutional, and market risks, including risks associated with erosion, compaction, fire, drought, flooding or waterlogging, salinization, acidification, contamination, pests or disease outbreaks, invasive species, loss of vegetation cover, discontinuation of management, land-tenure or stakeholder conflict, financial or institutional failure, changes in law or policy, climate change, and other relevant drivers.

The risk assessment shall inform and be consistent with the climate change adaptation plan required under the BBS. For the purposes of this methodology, the plan shall address soil-biodiversity risks associated with drought, flooding, waterlogging, erosion, salinization, temperature change, altered soil moisture, vegetation shifts, and other climate-related drivers relevant to the applicable soil biodiversity conservation outcome.

For each material risk, the Initiative holder shall document the cause, likelihood, potential consequence, affected area, affected indicator or biodiversity dimension, preventive measures, contingency measures, monitoring indicators, responsible party, and residual risk. The risk assessment shall be updated where monitoring results, external events, stakeholder information, legal changes, or changes in activity implementation indicate that the risk profile has materially changed.

14.3 Leakage and displacement of pressures

The initiative holder shall assess whether initiative activities displace biodiversity pressures beyond the initiative boundary.

For soil biodiversity initiatives, leakage and displacement of pressures may include, as applicable, displacement of tillage, grazing pressure, biomass extraction, residue removal, pesticide or fertilizer use, irrigation pressure, drainage impacts, soil disturbance, contamination, or sourcing impacts associated with compost, manure, biochar, microbial products, or other biological and organic inputs. The Initiative holder shall identify material leakage pathways, define monitoring indicators, implement mitigation measures, and apply conservative adjustments where material unmitigated leakage affects the integrity of the claimed soil biodiversity conservation outcome.

Potential leakage pathways may include, as applicable, the displacement outside the initiative boundary of grazing pressure, agricultural expansion, intensive tillage, pesticide use, residue burning, extraction of organic matter or biomass, waste or manure disposal, water withdrawal, pollution, infrastructure, traffic, or any other biodiversity-degrading activity that could reduce the integrity of the claimed soil biodiversity conservation outcome.

Where feasible, the leakage assessment shall distinguish between primary leakage occurring in neighboring or directly connected areas and secondary leakage occurring at broader landscape, market, or supply-chain scales.

The Initiative holder shall define the leakage assessment area, identify baseline activities and actors, establish leakage indicators, monitor relevant activity data, implement mitigation measures, quantify material leakage, and apply a conservative deduction where material leakage is identified.

Where significant leakage cannot be quantified reliably, the initiative holder shall apply a conservative proportional deduction approved under the BBS.

Significant unmitigated leakage shall make the affected outcome ineligible for issuance.

14.4 Reversal

For the purposes of this methodology, reversals shall be distinguished from measurement corrections and attribution changes. An ecological reversal occurs where a previously verified soil biodiversity conservation outcome is partially or totally lost due to deterioration in the direct biological indicators or associated soil biodiversity condition. A measurement reversal occurs where subsequent evidence demonstrates that a previously quantified outcome was overstated because of sampling, laboratory, analytical, statistical, or data-management error. An attribution reversal occurs where new evidence demonstrates that the previously claimed outcome cannot be attributed to the Initiative to the extent originally determined.

The treatment of each case shall be conservative and shall follow the applicable BBS requirements, the audit findings, and BioCarbon's conformity determination. Measurement corrections and attribution changes shall not be treated as ecological recovery or deterioration unless supported by direct biological evidence.

A reversal occurs where a previously credited soil biodiversity outcome is subsequently lost in whole or in part.

A reversal may result from any event, action, omission, or external disturbance that materially reduces a previously credited soil biodiversity conservation outcome. Such causes may include cessation or failure of initiative activities, return to harmful management, contamination, erosion or loss of soil, severe climatic or hydrological disturbance, fire, invasive species, land-use change, governance or tenure failure, or another relevant driver that reduces the previously credited outcome. A confirmed reversal shall be quantified relative to the previously credited conservative condition.

The reversed BioCredit quantity for stratum h and monitoring period t shall be calculated as:

$$BC_{rev,h,t} = \max(0, BC_{prev,h} - BC_{curr,h,t})$$

Equation 15

Where:

- $BC_{rev,h,t}$ = reversed BioCredits for stratum h and monitoring period t;
- $BC_{prev,h}$ = previously issued BioCredits associated with the affected soil biodiversity conservation outcome in stratum h; and
- $BC_{curr,h,t}$ = BioCredits that would be supported by the current conservative soil biodiversity condition for the affected stratum and monitoring period, after applying the applicable pathway-specific eligibility, uncertainty, leakage, and integrity requirements.

The total reversed BioCredit quantity for monitoring period (t) shall be calculated as:

$$BC_{rev,t} = \sum_{h \in H_t} BC_{rev,h,t} \quad \text{Equation 16}$$

Where:

$BC_{rev,t}$ = total reversed BioCredits for monitoring period t; and
 H_t = set of affected strata or spatial accounting units in monitoring period t.

14.5 Reversal detection

A potential reversal shall be investigated where:

- (a) the SBI point estimate falls below the previously credited condition;
- (b) either direct biodiversity dimension declines materially;
- (c) a major disturbance affects the initiative area;
- (d) the approved activity ceases;
- (e) monitoring is not completed as required;
- (f) safeguards or legal conditions are no longer fulfilled; or
- (g) a material data-quality failure is identified.

Where uncertainty prevents immediate confirmation, prospective issuance shall be suspended for the affected area until the condition is resolved.

14.6 Treatment of reversals

Where a binding BioCarbon normative document establishes a risk-reserve or buffer mechanism applicable to the initiative, the corresponding provisions shall apply. In all other cases, confirmed reversals shall be addressed through the measures established by the BBS and the applicable BioCarbon Program procedures.

14.7 Preventive and corrective measures

Risk-management measures may include diversified management, erosion and fire control, contamination prevention, emergency response, long-term agreements, financial reserves, insurance or risk-sharing arrangements, stakeholder agreements, alternative management capacity, seed, inoculum, or planting-material contingency plans, monitoring intensification, adaptive-management triggers, or other measures appropriate to the identified risks.

Corrective measures shall be proportionate to the cause, area, severity, and duration of the loss.

15 Assumptions and limitations of the methodology

The methodology assumes that the selected microbial and faunal indicators are responsive to the pressures and activities identified in the theory of change; that stratification and sampling capture the principal sources of heterogeneity; that baseline, control, and monitoring campaigns are sufficiently comparable; and that the approved sampling and analytical procedures provide sufficient sensitivity, precision, and reproducibility to detect the target effect size specified for statistical-design purposes with the required power. Statistical detectability shall not, by itself, establish ecological materiality.

Soil biodiversity is highly variable across short distances and through time. Molecular methods are affected by extraction, primer, amplification, sequencing and database biases; metabarcoding primarily provides relative molecular observations and does not necessarily demonstrate organism viability. Faunal groups may be patchy and difficult to identify, reference datasets may be incomplete, and different biological components may respond at different rates. Biological functions such as respiration or enzyme activity can change without a corresponding increase in taxonomic or community integrity.

The SBI is an accounting index derived from an approved indicator set. It is not a complete species inventory, a universal measure of ecological integrity, an estimate of intrinsic value, proof that every soil function improved, or evidence of equivalence with biodiversity elsewhere. Results shall not be extrapolated across materially different soil groups, ecological zones, land uses, sampling depths, methods, reference domains or time periods without an approved transferability assessment. Where data or methodological limitations prevent a reliable conservative estimate, the affected area or period shall not generate BioCredits.

16 Quality assurance

Results quantified under this methodology shall be subject to internal quality assurance and independent audit in accordance with the BBS, the applicable BioCarbon Audit Manual, and the requirements established in this methodology.

The Initiative holder shall conduct an internal quality review before submission to a CAB. The review shall confirm the applicability of the methodology, area eligibility, conservation activity category, baseline and counterfactual, additionality, theory of change, sampling design, field implementation, laboratory and molecular QA/QC, data completeness, indicator and SBI calculations, uncertainty treatment, leakage, risk and reversal assessment, safeguards, double-counting controls, data traceability, and BioCredit calculation. Where organizational capacity permits, the internal review shall be performed by a person who did not conduct the relevant calculation or analysis.

Analytical methods shall have documented performance information appropriate to their purpose, including accuracy, precision, repeatability, reproducibility, robustness, measurement uncertainty, quality-control criteria, and the applicable soil or analytical domain.

Laboratories shall demonstrate competence through accreditation, proficiency testing, interlaboratory comparison, validated in-house methods, documented staff competence, internal controls, control charts, external technical review, or another evidence-based demonstration accepted by BioCarbon. Where a molecular method lacks a formal accreditation pathway, the laboratory shall document equivalent controls and analytical validation.

The same field, laboratory, molecular, bioinformatic, and statistical methods shall be maintained between baseline and monitoring wherever feasible. Where a material methodological change is necessary, the Initiative holder shall justify the change, demonstrate comparability through archived samples, overlap analysis, bridging studies, conversion or harmonization procedures, or another scientifically valid approach, and propagate any additional uncertainty. Where comparability cannot be demonstrated, the affected data, area, stratum, or monitoring period shall not be used to increase BioCredit issuance. The more conservative result shall apply.

17 References

The references listed in this section are cited in the body, tables, or appendices of this methodology. Documents that constitute normative requirements for its application are identified separately in Section 5.

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ISO 11063. Soil quality — Direct extraction of soil DNA. Current applicable edition.

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ISO 16072. Soil quality — Laboratory methods for determination of microbial soil respiration. Current applicable edition.

ISO 17601. Soil quality — Estimation of abundance of selected microbial gene sequences by quantitative polymerase chain reaction from DNA directly extracted from soil. Current applicable edition.

ISO 20130. Soil quality — Measurement of enzyme activity patterns in soil samples using colorimetric substrates in micro-well plates. Current applicable edition.

ISO 23611 series. Soil quality — Sampling of soil invertebrates. Current applicable editions.

ISO/IEC 17025. General requirements for the competence of testing and calibration laboratories. Current applicable edition.

Appendix A. Glossary of terms

The definitions established in the BBS shall apply. The following methodology-specific terms shall also apply.

Achieved minimum detectable effect — MDE

The smallest effect that the approved statistical design is capable of detecting with the specified Type I error rate and statistical power, given the final sample size, variance, correlation structure, allocation, and other design assumptions. The achieved MDE describes the statistical sensitivity of the design and does not, by itself, establish ecological materiality.

Amplicon sequence variant — ASV

A unique DNA sequence inferred after correction of sequencing errors within an amplicon dataset and used as a reproducible molecular feature for community analysis.

Baseline scenario

The most plausible trajectory of soil biodiversity in the absence of the initiative.

Before–After–Control–Impact design — BACI design

A comparative design that estimates the effect of an initiative by comparing the change observed over time within the initiative area with the contemporaneous change observed within a comparable control area.

Biological-function indicator

A measurement of a biological process or activity, such as respiration, decomposition, or enzyme activity. It supports ecological interpretation, causal evidence, and no-harm assessment, but does not, by itself, constitute a soil biodiversity conservation outcome or independently generate BioCredits.

BioCredit

See the definition established in the BBS. Under this methodology, the quantity of BioCredits is expressed in SBI point-hectares.

Composite sample

A sample formed by combining subsamples collected within one independent sampling unit. The resulting composite sample represents one field observation; its constituent subsamples are not independent replicates.

Control area

An area representing the management and ecological conditions expected in the absence of the initiative and monitored contemporaneously with the initiative area.

Counterfactual

The condition or trajectory that would most plausibly have occurred without the initiative.

Critical direct biological indicator

A direct biological indicator identified in the Indicator Dictionary for which a material adverse change may invalidate or restrict positive BioCredit quantification and shall not be concealed through aggregation within the MBS, FBS, or SBI.

Direct biological indicator

An indicator measuring the diversity, composition, abundance, biomass, trophic structure, or another direct attribute of soil organisms.

Direct biodiversity dimension

An aggregated component of direct soil biodiversity condition used to calculate the SBI. Under this methodology, the direct biodiversity dimensions are microbial biodiversity, represented by the MBS, and soil-faunal biodiversity, represented by the FBS.

Ecological materiality threshold

A pre-specified and scientifically justified threshold representing a difference in biodiversity condition that is considered ecologically meaningful within an approved reference domain. It is distinct from statistical significance, statistical power, the target effect size used for power analysis, and the achieved minimum detectable effect.

Ecological reference

An area, dataset, or condition used to characterize ecological potential, target condition, or indicator scoring. It does not automatically represent the counterfactual.

Effective number of taxa

A Hill-number expression of diversity that converts an entropy or dominance index into the equivalent number of equally abundant taxa.

Faunal Biodiversity Score — FBS

The 0–100 score derived from approved soil-fauna indicators.

Hill numbers

A family of diversity measures parameterized by order q , including richness at $q=0$, exponential Shannon diversity at $q=1$, and inverse Simpson diversity at $q=2$.

Indicator Dictionary

The controlled document specifying the definition, method, unit, scoring function, reference domain, uncertainty, QA/QC, and decision rules for each indicator.

Initial condition

The measured condition of soil biodiversity at the beginning of the quantification period.

Leakage

Displacement of an activity or pressure that harms biodiversity from inside the initiative area to an area outside its boundaries.

Material decline

A negative difference between the monitored and applicable baseline conditions whose magnitude exceeds the approved adverse-change threshold after accounting for uncertainty.

Microbial Biodiversity Score — MBS

The 0–100 score derived from approved bacterial, archaeal, and fungal community indicators.

Monitoring period

The defined period for which activities and biodiversity outcomes are monitored, reported, audited, and considered for BioCredit issuance.

Non-compensation

A methodological rule under which positive performance in one direct biodiversity dimension or indicator shall not offset a material decline in another dimension or in a critical direct biological indicator.

Primary direct biological indicator

A direct biological indicator designated in the Indicator Dictionary as contributing to the calculation of the MBS or FBS and, consequently, to the SBI.

Reference domain

The ecological and analytical conditions within which an indicator scoring function is valid.

Reference-domain protocol

A documented technical specification defining the domain of validity, applicable biological indicators and modules, sampling and analytical methods, scoring functions, ecological benchmarks, indicator and dimension weights, materiality thresholds, and other decision rules required to calculate and interpret the SBI within a defined reference domain.

Reversal

A subsequent loss, in whole or in part, of a previously credited soil biodiversity conservation outcome.

Sampling unit

The independent spatial unit at which a field observation or composite sample is obtained.

SBI point-hectare

A standardized accounting unit used to express the quantity of verified soil biodiversity conservation outcomes under this methodology. It corresponds to one conservative SBI point associated with one hectare of eligible and adequately represented initiative area, where the applicable pathway-specific eligibility conditions have been met.

Note 1 to entry: An SBI point is an absolute unit of the 0–100 Soil Biodiversity Index and shall not be interpreted as a percentage change in biodiversity.

Note 2 to entry: An SBI point-hectare is an accounting convention and does not represent a physical unit, a universal ecological constant, or ecological equivalence among different soils, biological communities, reference domains, or geographic locations.

Note 3 to entry: Under this methodology, one BioCredit corresponds to one net SBI point-hectare after application of the applicable eligibility, uncertainty, materiality, leakage, and other required adjustments.

Soil biodiversity conservation outcome

A measurable result in the condition of soil microbial and faunal communities that is directly attributable to eligible preservation, ecological restoration, or sustainable-use activities and is determined relative to the applicable baseline scenario using the approved direct biological indicators and the Soil Biodiversity Index.

Note 1 to entry: Under this methodology, the quantified soil biodiversity conservation outcome is determined using the conservative monitored SBI, the applicable baseline or counterfactual, the approved outcome pathway, the eligible area, and the applicable uncertainty, materiality, leakage, and integrity requirements. The outcome shall not be interpreted as an automatic crediting of the difference between monitored and baseline SBI.

Note 2 to entry: The implementation of a management practice, or a change in a biological-function, physicochemical, management, climatic, hydrological, or landscape supporting variable, does not, by itself, constitute a soil biodiversity conservation outcome.

Note 3 to entry: Only outcomes that satisfy the applicable requirements for additionality, ecological materiality, uncertainty, non-compensation, safeguards, monitoring, independent audit, and BioCarbon conformity determination are eligible for BioCredit issuance.

Soil Biodiversity Index — SBI

A 0–100 composite index based on direct microbial and soil-faunal biodiversity indicators, aggregated using geometric means and non-compensation rules.

Spatial accounting unit

A geographically defined area within which the baseline condition, monitored SBI, soil biodiversity conservation outcome, pathway-specific eligibility, leakage treatment, and any subsequent reversal are tracked consistently. A spatial accounting unit may correspond to a stratum or to an approved subdivision of a stratum.

Stratum

A spatial subset of the initiative area defined by relatively homogeneous soil, ecological, land-use, management, or disturbance characteristics.

Supporting variable

A biological-function, physicochemical, management, pressure, climatic, hydrological, or landscape variable used for stratification, interpretation, attribution, safeguards, uncertainty, or risk assessment. A supporting variable does not form part of the MBS, FBS, or SBI and does not independently generate a soil biodiversity conservation outcome.

Target effect size for power analysis

The effect size specified before sampling and used to determine the sample size required to achieve the selected statistical power under the approved statistical design. It is a statistical-design parameter and does not automatically constitute an ecological materiality threshold.

Appendix B. Sampling design and field procedures

General design

Field sampling design and procedures shall follow the applicable parts of the ISO 18400 series or another validated sampling framework that provides equivalent requirements for sampling design, field implementation, sample handling, and documentation.

The sampling design shall represent all eligible strata, provide an unbiased or conservatively biased estimate of condition and change, permit uncertainty estimation, and support repeated monitoring. Sampling locations shall be selected using a probability-based design, such as spatially balanced random, stratified random, systematic random with a random origin, generalized random tessellation stratified sampling or a justified matched-pair design. Convenience sampling shall not be used for credit quantification.

The independent sampling unit is the field plot or point at which a biological observation or composite sample is obtained. Soil cores combined within that unit are subsamples and shall not be treated as independent replicates. Permanent or precisely relocatable units shall be used where feasible, with a rotating within-unit sublocation pattern to avoid repeatedly sampling the same disturbed hole.

Sample size and allocation

Sample size shall be determined for the primary direct biological indicators through power analysis or simulation of the statistical model planned for monitoring. The calculation shall incorporate the expected variance, a pre-specified target effect size for power-analysis purposes, a Type I error rate no greater than 5%, statistical power of at least 80%, repeated-measure correlation, spatial clustering, design effects, and expected sample loss.

The target effect size shall represent the smallest change that the proposed design is intended to detect with the specified statistical power. It shall be selected before monitoring results are evaluated and shall be documented together with its scientific, empirical, or management basis. The target effect size shall not automatically be used as the ecological materiality threshold for BioCredit quantification.

Where reliable prior variance information is unavailable, a pilot survey of at least ten independent sampling units per major provisional stratum shall be conducted. Pilot data may form part of the final baseline where all sampling, handling, analytical, and QA/QC procedures are consistent.

After the sampling design has been finalized, the initiative holder shall calculate and report the achieved minimum detectable effect for each primary indicator or direct biodiversity dimension. The achieved minimum detectable effect shall describe the sensitivity of the

approved statistical design and shall not be interpreted as evidence that a change of that magnitude is ecologically material.

Cochran's formula for estimating a population proportion shall not be used as the default procedure for continuous, count, multivariate, compositional, or repeated biodiversity indicators.

Where several primary indicators are used, the largest required sample size shall apply unless a justified multivariate power analysis is used.

$$n_h = \left[\left(\frac{(Z_{1-\alpha/2} + Z_{1-\beta})\sigma_{\Delta,h}}{\Delta_h^{target}} \right) \right]^2 \quad \text{Equation 17}$$

Where:

- n_h = number of independent sampling units required in stratum h;
- $\sigma_{\Delta,h}$ = expected standard deviation of the change in stratum h;
- Δ_h^{target} = target effect size used for power-analysis and sample-size determination;
- α = Type I error rate; and
- $1 - \beta$ = required statistical power.

Equation 17 is a simplified expression applicable to a normally distributed paired or before-after response under the assumptions stated above. Where the approved statistical design includes hierarchical sampling, non-normal distributions, multivariate community data, repeated measurements, spatial correlation, or unequal allocation, sample size shall be determined through simulation of the planned statistical model or another appropriate procedure.

Sampling effort may be allocated proportionally, equally among strata, through Neyman allocation based on variance, or through another statistically justified optimization. The selected allocation shall be established before monitoring results are examined.

Field collection and depth

Table B1. Default field units, depths and handling considerations

Component	Default field unit and depth	Key handling requirements
Microbial, biochemical and physicochemical soil	Composite of at least five spatially distributed cores within one independent sampling unit; primary mineral-soil layer 0-10 cm.	Use clean or sterile equipment; homogenize consistently; split aliquots before incompatible preservation steps.

Component	Default field unit and depth	Key handling requirements
Subsurface soil	Separate 10-30 cm layer where rooting, tillage, hydrology, amendment placement or the theory of change indicates a material subsurface response.	Do not combine with 0-10 cm unless the aggregation rule was specified in advance.
Organic horizon or litter	Sample separately where present and relevant.	Do not mix with mineral soil.
Nematodes and microarthropods	Separate cores or samples of standardized mass or volume under the applicable ISO 23611 method.	Maintain the extraction and preservation conditions required for the target group.
Earthworms and macrofauna	Standardized soil area or monolith, hand sorting or approved extraction under the applicable ISO 23611 method.	Record sampled area, depth, effort, life stage and biomass procedure.
Bulk density	Intact-volume cores at each depth for which stocks or volume-based variables are reported.	Avoid compaction or loss of fine material; record coarse fragments.

Rhizosphere and bulk-soil samples shall be defined and reported separately. Where the rhizosphere is assessed, the same plant species or functional group and comparable phenological stage shall be used. Sampling depth shall be measured from a defined surface reference, and litter, organic horizons and mineral soil shall not be combined unless the procedure is explicitly justified.

Temporal design, controls and reference areas

Baseline and monitoring campaigns shall use equivalent seasons, production-cycle stages and recent-management windows. Initiative and control areas shall be sampled within the same temporal window and, where feasible, within the same analytical batch. When two or more seasonal campaigns are required, each shall be analyzed separately before any annual aggregation. Seasonal values may be combined only through a pre-specified weighting procedure that reflects their ecological relevance or duration.

Control and reference areas shall use the same sampling design, depths, effort and methods as comparable initiative strata. Batch randomization shall include initiative and control samples. A sampling unit may be replaced only where it has been permanently lost, is unsafe or legally inaccessible, has been invalidated by an external event, or was incorrectly located. Replacement

shall follow the original probability-based procedure within the same stratum and shall not be selected because of its observed biodiversity condition.

Preservation, transport and field QA/QC

Table B2. Minimum preservation framework

Analysis	Preservation and transport
DNA and amplicon sequencing	Freeze promptly or use a validated nucleic-acid preservation medium; avoid repeated freeze-thaw cycles; document holding time and temperature.
Microbial biomass and respiration	Keep fresh under validated cool, aerobic conditions and analyze within the validated holding time; freezing shall be used only where the method has been validated for frozen material.
Enzyme activity	Follow the method-specific requirement for fresh, refrigerated, frozen or air-dried soil and maintain the same treatment across campaigns.
Physicochemical analysis	Prepare and preserve according to the parameter-specific method; air-dry only where compatible with the analysis.
Fauna	Extract promptly or preserve using a validated group-specific method; record preservative, extraction time and identification procedure.

Field QA/QC shall include equipment decontamination, sample-label reconciliation, coordinate validation, completeness review, preservation checks, chain-of-custody verification and field duplicates for a documented proportion of sampling units. Molecular field blanks shall be included where contamination risk is material. Duplicates evaluate collection and small-scale variability; they do not replace independent replication.

Appendix C. Uncertainty analysis and conservative quantification

Uncertainty framework

The initiative holder shall identify, quantify, propagate and conservatively treat uncertainty affecting the SBI and BioCredit calculation. Relevant sources include spatial and temporal variability, field collection, subsampling, laboratory measurement, molecular extraction and sequencing, taxonomic assignment, bioinformatic processing, reference-domain selection, scoring functions, indicator weighting, counterfactual estimation, eligible area, missing data, leakage and methodological changes.

Indicator-level uncertainty shall be estimated through analytical propagation, non-parametric or parametric bootstrap, hierarchical modelling, Bayesian posterior simulation, Monte Carlo simulation or another statistically valid method. The method shall preserve the hierarchical and repeated-measures structure of the data. Rarefaction alone shall not be treated as a complete uncertainty analysis for sequencing data; coverage, batch effects, contaminant removal, compositionality and reasonable bioinformatic alternatives shall be considered.

Propagation and conservative estimate

For each simulation or bootstrap iteration, raw indicator values shall be resampled or simulated, indicator scores shall be recalculated, MBS and FBS shall be aggregated, SBI shall be recomputed, the soil biodiversity conservation outcome shall be estimated, and the BioCredit calculation shall be repeated. Uncertainty shall therefore be propagated through the complete calculation chain rather than applied only to the final point estimate.

The simulation-based procedure shall support the estimation of conservative inputs required to apply the BioCredit equations established in Section 12 and shall not create an independent crediting equation.

Where geometric aggregation is implemented through bootstrap, Monte Carlo, Bayesian posterior simulation, or another simulation-based procedure, the Initiative holder may apply a numerical regularization constant solely to avoid computational indeterminacy caused by zero values in stochastic iterations. The value of the regularization constant shall be pre-specified, materially negligible relative to the 0–100 SBI scale, applied consistently to monitored and baseline calculations, and assessed through sensitivity analysis.

Numerical regularization shall not convert a true ecological zero, missing data, analytical failure, omitted biological module, or insufficient sampling into a positive ecological score. Where a zero score results from the approved reference-domain scoring function, the non-compensatory interpretation of the geometric aggregation shall be preserved. The use, value, rationale, and effect of any regularization constant shall be documented and made available for audit.

Where uncertainty is propagated through bootstrap, Monte Carlo, Bayesian posterior simulation, or another valid simulation-based method, the monitored SBI, pathway-specific eligibility, gross BioCredit quantity, leakage, other deductions, and net BioCredit quantity shall be recalculated within each iteration.

For each iteration (b), the simulated gross BioCredit quantity for stratum (h) and monitoring period (t) shall be calculated as:

$$SBI_{cons,h,t} = Q_{0.10} \left(SBI_{h,t}^{(1)}, SBI_{h,t}^{(2)}, \dots, SBI_{h,t}^{(B)} \right) \quad \text{Equation 18}$$

$$BC_{gross,h,t} = A_{h,t} \times SBI_{cons,h,t} \times F_{elig,h,t}$$

$$BC_{net,t} = \max \left(0, \sum_{h \in H} BC_{gross,h,t} - L_t - D_t \right)$$

Where leakage is estimated proportionally, the leakage deduction shall be calculated as:

$$L_t = \lambda_t \times \sum_{h \in H} BC_{gross,h,t}$$

Where:

$SBI_{cons,h,t}$	= conservative monitored Soil Biodiversity Index for stratum <i>h</i> and monitoring period <i>t</i> ;
$Q_{0.10}$	= 10th-percentile operator, corresponding to a one-sided 90% lower confidence bound;
$SBI_{h,t}^{(b)}$	= monitored Soil Biodiversity Index calculated in simulation or bootstrap iteration <i>b</i> ;
B	= total number of valid simulation or bootstrap iterations;
$BC_{gross,h,t}$	= gross BioCredits for stratum <i>h</i> and monitoring period <i>t</i> ;
$A_{h,t}$	= eligible area of stratum <i>h</i> during monitoring period <i>t</i> , in hectares;
$F_{elig,h,t}$	= pathway eligibility factor for stratum <i>h</i> and monitoring period <i>t</i> ;
$BC_{net,t}$	= net BioCredit quantity for monitoring period <i>t</i> ;
H	= set of eligible strata or spatial accounting units included in the issuance calculation;
L_t	= leakage deduction for monitoring period <i>t</i> ;
D_t	= other applicable deduction for monitoring period <i>t</i> ; and
λ_t	= conservatively estimated leakage proportion between 0 and 1.

The simulation-based uncertainty analysis shall not treat ΔSBI as an independent crediting unit. Baseline or counterfactual uncertainty shall be incorporated through the pathway-specific eligibility assessment, materiality assessment, and any modelled uncertainty affecting the determination of the verified soil biodiversity conservation outcome.

Where eligible area is uncertain, the lower confidence estimate of area or the mapped area after exclusion of uncertain boundary polygons shall be used. Counterfactual uncertainty shall include control-site variability, matching uncertainty, historical trends, model parameters and structure, external drivers and the probability that baseline management continues. Where several counterfactuals are similarly plausible, the lowest credible outcome shall be used, or the alternatives shall be incorporated into the uncertainty distribution.

Missing data and sensitivity analysis

Sample loss and missing data shall be evaluated for mechanism, representativeness, statistical power and potential bias. Imputation may be used for supporting variables only where it was pre-specified, its uncertainty is propagated, and it does not increase the credited outcome. Where missing direct biological data prevent a reliable conservative estimate, the affected unit, stratum or period shall receive no BioCredits.

Sensitivity analysis shall examine reasonable alternatives for scoring benchmarks, distance metrics, indicator weights, treatment of introduced organisms, influential observations, counterfactual assumptions, spatial and temporal models, missing-data procedures, leakage and risk assumptions. Where a reasonable alternative materially lowers the estimated outcome and cannot be rejected scientifically, the more conservative result shall be used. A fixed default deduction shall be used only where quantitative uncertainty cannot reasonably be estimated, the reason is documented and BioCarbon approves the deduction.

The Uncertainty Report shall identify data sources, methods, software, assumptions, input distributions, dependence structures, the number of simulations, indicator- and dimension-level uncertainty, SBI and counterfactual uncertainty, gross and net BioCredit distributions, the conservative lower-bound result and all sensitivity analyses. Code, input data, random seeds and outputs necessary to reproduce the assessment shall be retained for audit.

Sensitivity analysis shall evaluate the influence of the aggregation function, in addition to scoring benchmarks, reference domains, distance metrics, and indicator weights. The approved weighted geometric mean shall be compared with plausible alternative aggregation functions representing different degrees of compensation, such as an intermediate power mean and a weighted arithmetic mean.

The analysis shall evaluate effects on the MBS, FBS, monitored SBI, conservative monitored SBI, pathway-specific eligibility assessment, and the resulting BioCredit quantity across the range of conditions represented by the pilot and reference-domain datasets.

Once approved for a reference domain, the aggregation function shall remain fixed and shall be applied consistently to baseline and monitored conditions. Initiative holders shall not select an aggregation function on the basis of which alternative produces the highest SBI or BioCredit quantity.

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