SOCIALCARBON®

SCM0009 - Methodology for Afforestation, Reforestation, Revegetation

Document Prepared by the Social Carbon Foundation

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Contents

Methodology Details

1. Sources

This methodology uses the following sources:

- SOCIALCARBON Standard v6.1
- SOCIALCARBON Standard Definitions
- AR-ACM0003 - Afforestation and reforestation of lands except wetlands v2.0
- VM0047 – Afforestation, Reforestation and Revegetation v1.0
- Gold Standard Methodology for Afforestation/Reforestation (A/R) GHG Emission Reduction & Sequestration

Please view the 10. References section of this document to see the full list of sources used to develop this methodology.

2. Summary description of the Methodology

Revitalizing forests presents a chance to safeguard the integrity of watershed processes and functions, alleviate the decline in biodiversity, address climate change impacts, and comply with regulations such as forest certification that oversee the global trade of forest products[1]. Native forest restoration efforts aim to improve the provision of ecosystem services[2].

This methodology provides a means to quantify net GHG emission removals (NERs) from project activities that plant and restore native forest habitats. In doing so, it aims to facilitate the implementation and scaling up of native forest restoration efforts globally.

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

The methodology supports both active and passive restoration[3] project activities. Depending on the type of project activities implemented, the methodology has provisions for monitoring to demonstrate

[1] Verdone and Seidl, 2017; Höhl et al., 2020; Jones et al., 2022

[2] Allison, 2004; Little and Lara, 2010; Clewell and Aronson, 2013; McDonald et al., 2016.

[3] Studies indicate that natural regeneration can take several decades, highlighting the need for assisted regeneration to manage barriers to regeneration and achieve cost-effective large-scale restoration (Aide et al., 2000; Letcher and Chazdon, 2009; Holl & Aide, 2010; Crouzeilles et al., 2020)

additionality and determine the crediting baseline at every verification. Namely, if the project has a close proximity to native forests[4] or is planning to implement passive restoration project activities. Under these circumstances a dynamic performance benchmark is calculated from ex-post observations of business-as-usual changes in vegetative cover in matched control areas.

3. Definitions

In addition to the definitions set out in the latest version of the SOCIALCARBON Standard Definitions, the following definitions apply to this methodology:

Active restoration
The direct implementation of activities (e.g. manual planting, broadcast seeding) to start or accelerate the recovery process or attempt to change the site's ecological succession.

Control plot
Areas situated beyond the project area, chosen due to their resemblance to project plots, and where the stocking index is observed through remote sensing throughout the crediting period.

Donor pool area
Geospatial domain sharing similar attributes to the project plot, from which control plots can be selected.

Matching covariates
Continuous variables used to match control plots with each project plot, encompassing at least historical and initial stocking indices (SI).

Multivariate distance metric
Metric that calculates the distance between two vectors (e.g., Mahalanobis distance), employed to measure the match or "closeness" between potential control plots and project plots.

Passive restoration
Allowing natural succession to occur in an ecosystem after removing sources of disturbance.

Project plot
Representatively sampled plots of up to 10 ha from the project area and on which the stocking index (SI) is evaluated via remote sensing.

Stocking index (SI)
An unspecified remote sensing metric that has demonstrated correlation with terrestrial aboveground carbon stocks (e.g., normalized difference fraction index from Landsat imagery, or average canopy height derived from LiDAR).

Woody biomass
Biomass in plants with hard, lignified stems, for example, trees, shrubs, palms and bamboo.

[4] Within 200 meters of a native forest. Crouzeilles et al. (2020) found that 90% of passive regeneration occurred within 192 m of forested areas.

4. Applicability Conditions

This methodology is applicable under the following conditions:

a) Projects may include active and/or passive restoration to increase vegetative cover;

b) Project activities do not take place on tidal wetlands;

c) Project activities are not carried out on organic soils or in wetlands that involve altering the water table;

d) The introduction of plant species not naturally found in organic soils or wetlands is regarded as a manipulation of the water table;

e) In cases where invasive species are found within the project area, the project is required to implement measures for their removal and management;

f) Project activities do not result in a net negative climate impact due to Albedo offset[5];

g) Project proponents must document the project's proposed approach to stabilizing project carbon stocks after the planned project duration[6]. Evidence may include one or more of the following:

   a) Demonstration of projected financial sustainability after the project end date period;

   b) A specific plan to attain legal protection beyond the project duration; or

   c) A curriculum of ongoing capacity-building that facilitates long-term carbon stock stewardship.

h) Any soil disturbance from the project activity (i.e., from site preparation):

   a) occurs only once during the project crediting period (i.e., at site preparation); or

   b) does not entail soil inversion beyond a depth of 25 cm (e.g., as would occur with a moldboard plow).

In addition to the above applicability conditions, dependent on the ARR approach utilised by the project the following conditions must also be met:

[5] Hasler et al. (2024); Thompson et al. (2009; Kirschbaum et al. (2011) indicate that albedo change as a result of ARR may offset any positive climate impacts delivered by projects. This applicability condition shall be evidenced either through peer-reviewed literature or validated remote sensing approaches with known uncertainty.

[6] Under the SOCIALCARBON Standard, crediting periods are 10 years and may be renewed up to a project duration of 100 years. Projects with a planned duration of less than 100 years must demonstrate they have interventions planned to promote the stabilisation of carbon stocks delivered by the project. E.g. a 50 year project obtains legal protection on the land to prevent non-sustainable land use after the project ends.

Table 1: Additional applicability conditions for specific ARR approaches

	Afforestation/Reforestation	Agroforestry
Minimum % of native species	100%	60%
% of each species	No species should represent more than 50% of total individuals planted. **Note**: In ecosystems where fewer species dominate this criterion doesn't apply[7].	No species represent more than 40% individuals planted.
Minimum number of native species planted	Temperate climate: 4 species Tropical climate: 15 species Dry climate: 4 species **Note**: In ecosystems where fewer species dominate this criterion doesn't apply[7].	Temperate climate: 2 species Tropical climate: 8 species Dry climate: 4 species **Note**: In ecosystems where fewer species dominate this criterion doesn't apply[7].
Sourcing of seeds	80% seeds collected within 250km radius of project area[8].	80% seeds collected within 250km radius of project area[8].
Harvesting of timber products	No harvesting of timber products (*or following documented best forestry practices). Only maintenance activities.	Max. 10% of total trees after 20 years (*or following documented best forestry practices). If for profit, only for community profits, as a sustainable income source or to continue with restoration activities. **Note:** projects are permitted to harvest and replace non-timber species where their maturity limits crop production e.g. Coffee. This harvesting must be accounted for using the long-term carbon benefit.

These additional applicability conditions are based on academic literature and the International Principles and Standards for the Practice of Ecological Restoration (by SER et al.), the Principles for Ecosystem Restoration to Guide the United Nations Decade 2021–2030 (by UN Environment Program, FAO et al.), the Road to Restoration (by WRI & FAO), and the Plant for the Planet Standards for Reforestation.

[7] Project proponents claiming that this is the case for their project must provide at least two sources of peer-reviewed literature which validate their claim.

[8] If this applicability condition cannot be met, project proponents must provide detailed evidence to justify why this is not possible and instead utilise seeds that are from the same biome as the project area.

5. Project Boundary

5.1 Carbon Pools

The spatial extent of the project boundary encompasses all lands subject to afforestation and/or reforestation.

Table 2 below identifies the carbon pools included or excluded from the project boundary.

Table 2 - Selected Carbon Pools under Baseline and Project Activity

Carbon Pools	Included?	Explanation
Aboveground woody biomass	Yes	This is a major carbon pool related to the project activity.
Aboveground non-woody biomass	No	Conservatively excluded.
Belowground woody biomass	Yes	This is a major carbon pool related to the project activity.
Deadwood	Optional	Optional – carbon pool may be impacted by the project activity.
Litter	Optional	Optional – carbon pool may be impacted by the project activity.
Soil Organic Carbon (SOC)	Yes/Optional	Must be included where soil disturbance from the project activity (e.g. during site preparation): 1. Occurs more than once during the project crediting period; or 2. Entails soil inversion beyond a depth of 25 cm (e.g., as would occur with a moldboard plow). Where the project activity can demonstrate that it does not cause soil disturbance the inclusion of this carbon pool is optional.

5.2 GHG Emission Sources

Table 3 presents the GHG sources included or excluded from the Project Boundary in this methodology.

Table 3 - GHG Sources included in or excluded from the Project Boundary

Source		Gas	Included?	Rationale
Project Emissions	Burning of biomass (natural or anthropogenic caused)	CO_2	No	Carbon stock decreases due to burning are accounted as a carbon stock change
		CH_4	Yes	May be a significant source
		N_2O	Yes	May be a significant source
	Emissions from nitrogen fertilizer	CO_2	No	Not applicable
		CH_4	No	Not applicable
		N_2O	Yes	Major emission source to be considered
	Burning of fossil fuels	CO_2	No	De minimis
		CH_4	No	De minimis
		N_2O	No	De minimis

This methodology exclusively quantifies net carbon removals. To ensure conservatism all baseline emissions are considered zero.

6. Baseline Scenario

The baseline scenario shall be established according to the most recent version of the "*Tool for the Demonstration and Assessment of Additionality in SOCIALCARBON Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*" (SCT0001)[9].

In addition:

Where the project activities focus on passive restoration, a performance benchmark must be used to set the crediting baseline. The performance benchmark, defined as the anticipated increase in vegetative cover under business-as-usual conditions compared to the project, is determined using data from

[9] SCT0001. Tool for the Demonstration and Assessment of Additionality in SOCIALCARBON Agriculture, Forestry and Other Land Use (AFOLU) Project Activities. Available at: https://www.socialcarbon.org/sct0001.

representative control plots located beyond the project area. Procedures to establish the performance benchmark are provided in Appendix 1.

Where the project activities focus on active restoration, and the project area is within 200 metres of a native forest, the area of the project within 200 metres of the native forest must also use a performance benchmark to set the crediting baseline.

Projects shall be exempt from the use of performance benchmarks if they can demonstrate that no natural regeneration has occurred in the area or been sustained[10] in the 10 years prior to the project start date, with no clearance of vegetation less than 3 years prior to the project start date.

If the active restoration project is not within 200 meters of a native forest, no performance benchmark is required.

Project areas that consisting of both passive restoration and active restoration zones shall demarcate the different zones relevant to their project area and conduct the monitoring procedures required for each zone as outlined above.

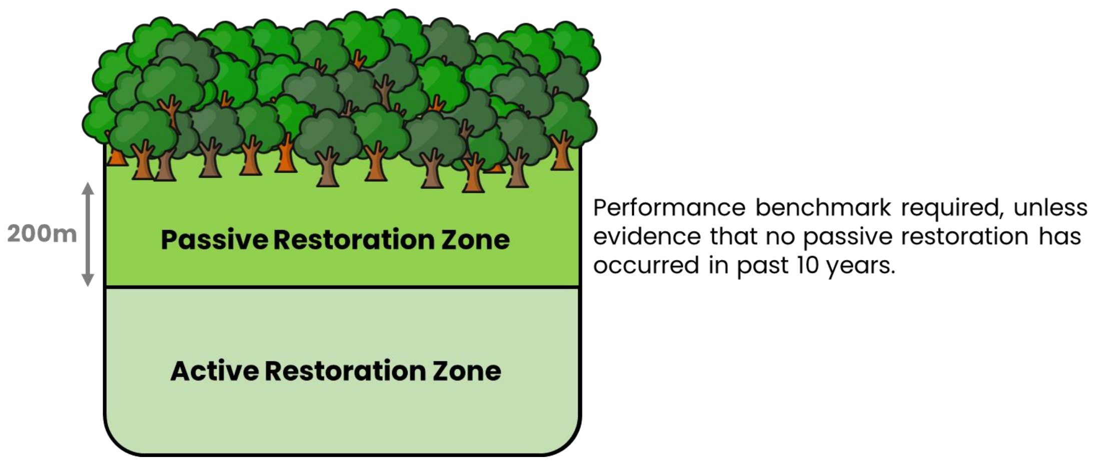

Figure 1: Illustration of forest proximity and performance benchmark requirements.

[10] To be eligible for this exemption, project proponents must demonstrate compliance with the requirements outlined in section 8.4.1 in particular (2), (3) or (4).

7. Additionality

This methodology uses a project method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the SOCIALCARBON Methodology Requirements.

Step 2: Project Method

The project activity shall apply the additionality analysis method set out in the latest version of the *SOCIALCARBON Tool for the Demonstration and Assessment of Additionality for AFOLU project activities (SCT0001)* to determine that the proposed project activity is additional. Under this methodology, the project shall only assess regulatory surplus, investment barriers and common practice.

Where the adoption rate of the project activity (e.g. native tree planting) is below 15% (Mathur et al., 2007), the project activity is not common practice. Where the adoption rate equals or exceeds 15%, the project activity is common practice and is not additional.

8. Quantification of GHG Emission Removals

8.1 Baseline emissions

Emissions in the baseline scenario shall be conservatively set to zero.

8.2 Baseline removals by sinks

Where the project proponent is able to demonstrate that a performance benchmark is not required, either for the entire project area or partially (e.g. half of the project area is greater than 200m from a native forest), as per Section 6, the carbon stock changes in the baseline scenario for these applicable areas are represented by the absence of planting and equal to zero.

Where vegetation, either trees or shrubs, exists in the project area and is not planned for removal prior to planting, the baseline shall be determined by estimating the ‘tree’ and ‘non-tree’ biomass that is present in the eligible planting area just prior to the planting start. To determine the Baseline of the eligible planting area the land shall be:

a) stratified according to its vegetation types (grassland, bushland, etc.), AND

b) for each of these strata scientifically based project-specific[11], regional or national default values shall be found which state ‘tree’ and ‘non-tree’ biomass of these vegetation types, OR

c) default values from the IPCC[12] shall only be used if no other values are available.

The Baseline carbon removals in a project planting area shall be deducted from the measured emission removals achieved in the first year of planting unless the project proponent can provide detailed evidence that no clearance of the baseline carbon stocks shall occur or that their accounting approach shall not account for any baseline vegetation.

The Baseline is not subject to monitoring or reassessment at the time of renewal of the crediting period.

Carbon stock changes in planting areas subject to the performance benchmarking must align with the requirements outlined in Section 8.7 (net GHG calculation) and Appendix 1.

8.3 Project Emissions

Project emissions resulting from use of fertilizer and biomass burning are calculated as follows:

$$PE_t = PE_{Fertilizer,t} + PE_{BBurnt,t} \quad \text{(Equation 1)}$$

Where:

PE_t	=	Project emissions in year t; tCO_2e
$PE_{Fertilizer,t}$	=	Project emissions from nitrogen fertiliser in year t; tCO_2e
$PE_{BBurnt,t}$	=	Project emissions from biomass burning in year t; tCO_2e

8.3.1 Emissions from Nitrogen Fertilizer

Where nitrogen fertilizer is applied due to the project activity, nitrous oxide emissions are calculated as follows:

$$PE_{Fertilizer,t} = PE_{Ndirect,t} + PE_{Nindirect,t} \quad \text{(Equation 2)}$$

Where:

$PE_{Fertilizer,t}$	=	Project emissions from nitrogen fertiliser in year t; tCO_2e
$PE_{Ndirect,t}$	=	Direct nitrous oxide emissions resulting from fertilizer usage in the project scenario in the monitoring period ending in year t; tCO_2e

[11] Project-specific default values are generated through a ‘tree’ and ‘non-tree’ inventory on the project area.

[12] Default values are found e.g. in the IPCC Guidelines for National GHG Inventories https://www.ipccnggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch04_Forest%20Land.pdf

$PE_{Nindirect,t}$	=	Indirect nitrous oxide emissions resulting from fertilizer usage in the project scenario in the monitoring period ending in year t; tCO_2e

$$PE_{Ndirect,t} = (F_{SN,t} + F_{ON,t}) \times EF_{Ndirect} \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 3)}$$

Where:

$PE_{Ndirect,t}$	=	Direct nitrous oxide emissions resulting from fertilizer usage in the project scenario in the monitoring period ending in year t; tCO_2e
$F_{SN,t}$	=	Synthetic N fertilizer applied in the project scenario in year t; t N
$F_{ON,t}$	=	Organic N fertilizer applied in the project scenario in year t; t N
$EF_{Ndirect}$	=	Emission factor for nitrous oxide emissions from N additions due to synthetic fertilizers, organic amendments and crop residues; t N_2O-N/t N applied
$\frac{44}{28}$	=	Ratio of molecular weight of N2O to molecular weight of N (applied to convert N_2O-N emissions to N_2O emissions); unitless
GWP_{N2O}	=	Global warming potential for Nitrous Oxide; dimensionless

$$F_{SN,t} = M_{SF,t} \times NC_{SF,t} \quad \text{(Equation 4)}$$

Where:

$F_{SN,t}$	=	Synthetic N fertilizer applied in the project scenario in year t; t N
$M_{SF,t}$	=	Mass of N-containing synthetic N fertilizer applied in the project scenario in year t; t fertilizer
$NC_{SF,t}$	=	Nitrogen content of synthetic N fertilizer applied in the project scenario in year t; t N/t fertilizer

$$F_{ON,t} = M_{OF,t} \times NC_{OF,t} \quad \text{(Equation 5)}$$

Where:

$F_{ON,t}$	=	Organic N fertilizer applied in the project scenario in year t; t N
$M_{OF,t}$	=	Mass of N-containing organic N fertilizer applied in the project scenario in year t; t fertilizer
$NC_{OF,t}$	=	Nitrogen content of organic N fertilizer applied in the project scenario in year t; t N/t fertilizer

Indirect nitrous oxide emissions due to fertilizer use in the project scenario are quantified as follows:

$$PE_{Nindirect,t} = Nfert_{volat,t} + Nfert_{leach,t} \quad \text{(Equation 6)}$$

Where:

$PE_{Nindirect,t}$	=	Indirect nitrous oxide emissions resulting from fertilizer usage in the project scenario in the monitoring period ending in year t; tCO_2e
$Nfert_{volat,t}$	=	Indirect nitrous oxide emissions produced from atmospheric deposition of Nitrogen volatized resulting from fertilizer applied in the project scenario in year t; tCO_2e
$Nfert_{leach,t}$	=	Indirect nitrous oxide emissions produced from leaching and runoff of Nitrogen resulting from fertilizer applied in the project scenario in year t; tCO_2e

$$Nfert_{volat,t} = [(F_{SN,t} \times FRAC_{GASF}) + (F_{ON,t} \times FRAC_{GASM})] \times EF_{Nvolat} \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 7)}$$

Where:

$Nfert_{volat,t}$	=	Indirect nitrous oxide emissions produced from atmospheric deposition of Nitrogen volatized resulting from fertilizer applied in the project scenario in year t; tCO_2e
$F_{SN,t}$	=	Synthetic N fertilizer applied in the project scenario in year y; t N
$F_{ON,t}$	=	Organic N fertilizer applied in the project scenario in year y; t N
$FRAC_{GASF}$	=	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NO_x; dimensionless
$FRAC_{GASM}$	=	Fraction of all organic N added to soils that volatilizes as NH_3 and NO_x; dimensionless
EF_{Nvolat}	=	Emission factor for nitrous oxide emissions from atmospheric deposition of Nitrogen volatized resulting from fertilizer applied in the project scenario in year t; t N_2O-N /(t NH_3-N + NO_x-N volatized
$\frac{44}{28}$	=	Ratio of molecular weight of N2O to molecular weight of N (applied to convert N_2O-N emissions to N_2O emissions); unitless
GWP_{N2O}	=	Global warming potential for Nitrous Oxide; dimensionless

$$Nfert_{leach,t} = (F_{SN,t} + F_{ON,t}) \times FRAC_{LEACH} \times EF_{Nleach} \times \frac{44}{28} \times GWP_{N2O} \quad \text{(Equation 8)}$$

Where:

$Nfert_{leach,t}$	=	Nitrous oxide emissions due to indirect fertilizer use in the project scenario for in year t; tCO2e
$F_{SN,t}$	=	Synthetic N fertilizer applied in the project scenario in year y; t N
$F_{ON,t}$	=	Organic N fertilizer applied in the project scenario in year y; t N

$FRAC_{LEACH}$	=	Fraction of N added (synthetic or organic) to soils that is lost through leaching and runoff, in regions where leaching and runoff occurs; dimensionless. For wet climates[13] or in dry climate regions where irrigation (other than drip irrigation) is used, a value of 0.24 is applied. For dry climates, a value of zero is applied.
EF_{Nleach}	=	Emission factor for nitrous oxide emissions from leaching and runoff; t N_2O-N / t N leached and runoff
$\frac{44}{28}$	=	Ratio of molecular weight of N2O to molecular weight of N (applied to convert N_2O-N emissions to N_2O emissions); unitless
GWP_{N2O}	=	Global warming potential for Nitrous Oxide; dimensionless

8.3.2 Emissions from Biomass Burning

$$PE_{BBurnt,t} = A_{Burnt,t} \times \sum_{g=1}^{G}(GWP_g \times EF_g \times B_{AGB,t} \times COMF \times 10^{-3}) \quad \text{(Equation 9)}$$

Where:

PE_{BBurnt,t_t}	=	Project emissions from biomass burning in year t; tCO_2e
$A_{Burnt,t}$	=	Area burned in the monitoring interval ending in year t; ha
GWP_g	=	Global warming potential for gas g; dimensionless
EF_g	=	Emission factor for gas g; kg gas/t d.m. burned
$B_{AGB,t}$	=	Average aboveground biomass stock subject to burning in the project scenario in year t; t d.m./ha
COMF	=	Combustion factor; dimensionless
g	=	*1, …, G* Greenhouse gases (methane and nitrous oxide); dimensionless
10^{-3}	=	Conversion of kg CO_2e to tCO_2e

The average aboveground biomass stock subject to burning is estimated as follows:

$$B_{AGB,t} = (C_{Woody\_AGB,t-1} + C_{DW,t-1} + C_{Litter,t-1}) \times \frac{1}{CF} \quad \text{(Equation 10)}$$

[13] Wet climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climates occur in temperate and boreal zones where the ratio of annual precipitation : potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm.

Where:

$B_{\text{AGB},t}$	=	Average aboveground woody biomass stock subject to burning in the project scenario in year t; t d.m./ha
$C_{Woody\_AGB,t-1}$	=	Average carbon stock in aboveground woody biomass in the project scenario at the end of t-1; tC/ha
$C_{DW,t-1}$	=	Average carbon stock in Deadwood in the project scenario at the end of t-1; tC/ha
$C_{Litter,t-1}$	=	Average carbon stock in litter in the project scenario at the end of t-1; tC/ha
CF	=	Carbon Fraction of dry biomass; tC/t d.m.

Note: If a project is in its first monitoring period, t-1 shall be the values for each parameter measured at the beginning of the monitoring period.

8.4 Project Removals

Project proponents should use the following equations to quantify the project removals achieved.

$$\Delta C_t = \Delta C_{Woody,t} + \Delta C_{DW,t} + \Delta C_{Litter,t} + \Delta C_{SOC,t} \quad \text{(Equation 11)}$$

Where:

ΔC_t	=	Project GHG removals by sinks in year t; tCO_2e
$\Delta C_{Woody,t}$	=	Change in carbon stock from woody biomass within the project boundary in year t; tCO_2e
$\Delta C_{DW,t}$	=	Change in carbon stock from deadwood within the project boundary in year t; tCO_2e
$\Delta C_{Litter,t}$	=	Change in carbon stock from litter within the project boundary in year t; tCO_2e
$\Delta C_{SOC,t}$	=	Change in carbon stock from soil organic carbon within the project boundary in year t; tCO_2e

Where projects establish the initial stocks at t > 0 (i.e. not the first monitoring period), the year of initial measurement (i.e. t-1) is substituted for t=0 in all project stock change equations calculating stock change through year t. Note, this does not affect the project start date which remains as t=0.

8.4.1 Woody Biomass

The change in carbon stock in woody biomass is estimated using the stock difference method (Bird et. al., 2010), which estimates the difference in carbon stocks at two points in time.

$$\Delta C_{Woody,t} = A \times \left(\left(C_{Woody,t} - C_{Woody,t-1} \right) \times \frac{44}{12} \right)$$ (Equation 12)

Where:

$\Delta C_{Woody,t}$	=	Change in carbon stock from woody biomass within the project boundary in year t; tCO_2e
A	=	Area; ha
$C_{Woody,t}$	=	Average carbon stock in woody biomass in the project scenario in year t; tC/ha
$C_{Woody,t-1}$	=	Average carbon stock in woody biomass in the project scenario in year t-1; tC/ha
$\frac{44}{12}$	=	Ratio of molecular weight of carbon dioxide to carbon; unitless

$$C_{Woody,t} = C_{Woody\_ABG,t} \times (1 + \mathrm{R})$$ (Equation 13)

Where:

$C_{Woody,t}$	=	Average carbon stock in woody biomass in the project scenario in year t; tC/ha
$C_{Woody\_ABG,t}$	=	Average carbon stock in aboveground woody biomass in the project scenario in year t; tC/ha
R	=	Root to shoot ratio; t root d.m./t shoot d.m

Pre-existing woody biomass

Measurements and extrapolations for pre-existing woody biomass are required using Equation (13) at t=0, just before the commencement of the project activity (e.g., prior to site preparation). If initial stocks are measured at t > 0, pre-existing woody biomass is considered equivalent to the initial stock measurement. Any removal of pre-existing woody biomass as part of the project activity (e.g., during site preparation) needs to be estimated using the stock difference method. If the slope of a linear regression of stocking index values (refer to Appendix 1) from time t= − 10 to t=0, encompassing site preparation, is both significant and negative, it suggests the clearing of pre-existing biomass. In such instances, the project proponent is required to demonstrate that the clearing was not conducted to generate GHG credits, as outlined below:

1) The prior clearing was the result of natural disturbances such as fires, hurricanes, or floods (e.g., using aerial imagery); or
2) The biomass cleared was invasive or was not native to the project area (e.g. commercial eucalyptus plantation in Brazil) and removal was required for native restoration to be possible; or
3) The prior clearing was conducted by actors with no relationship to the project proponent or landowner (e.g., via community surveys or law enforcement records).

Where it is not possible to provide such evidence, the project is ineligible.

If point 2 (removal of invasive or non-native species) was conducted by the project proponent the loss in carbon stocks must be accounted for and deducted in the first year of issuance.

8.4.2 Dead wood

The change in dead wood in the project scenario is estimated as follows:

$$\Delta C_{DW,t} = A \times \left(\left(C_{DW,t} - C_{DW,t-1} \right) \times \frac{44}{12} \right) \quad \text{(Equation 14)}$$

Where:

$\Delta C_{DW,t}$	=	Change in carbon stock from dead wood within the project boundary in year t; tCO_2e
A	=	Area; ha
$C_{DW,t}$	=	Average carbon stock in dead wood in the project scenario in year t; tC/ha
$C_{DW,t-1}$	=	Average carbon stock in dead wood in the project scenario in year t-1; tC/ha
$\frac{44}{12}$	=	Ratio of molecular weight of carbon dioxide to carbon; unitless

Dead wood may comprise two components: standing dead wood that is fully dead (i.e., absence of green leaves and green cambium) and lying dead wood.

$$C_{DW,t} = (B_{SDW,t} + B_{LDW,t}) \times \text{CF} \quad \text{(Equation 15)}$$

Where:

$C_{Woody,t}$	=	Average carbon stock in woody biomass in the project scenario in year t; tC/ha
$B_{SDW,t}$	=	Average biomass of standing deadwood in the project scenario in year t; t.d.m/ha
$B_{LDW,t}$	=	Average biomass of lying deadwood in the project scenario in year t; t.d.m/ha
CF	=	Carbon fraction of dry biomass; tC/t d.m

8.4.3 Litter

The change in litter in the project scenario is estimated as follows:

$$\Delta C_{Litter,t} = A \times \left(\left(C_{Litter,t} - C_{Litter,t-1} \right) \times \frac{44}{12} \right) \quad \text{(Equation 16)}$$

Where:

$\Delta C_{Litter,t}$	=	Change in carbon stock from litter within the project boundary in year t; tCO_2e
A	=	Area; ha
$C_{Litter,t}$	=	Average carbon stock in litter in the project scenario in year t; tC/ha
$C_{Litter,t-1}$	=	Average carbon stock in litter in the project scenario in year t-1; tC/ha
$\frac{44}{12}$	=	Ratio of molecular weight of carbon dioxide to carbon; unitless

$$C_{\text{Litter},t} = DM_{Litter,t} \times \text{CF} \quad \text{(Equation 17)}$$

Where:

$C_{Litter,t}$	=	Average carbon stock in litter in the project scenario in year t; tC/ha
$DM_{Litter,t}$	=	Average litter dry mass per hectare in the project scenario in year t; t.d.m/ha
CF	=	Carbon fraction of dry biomass; tC/t.d.m

8.4.4 Soil Organic Carbon

The change in Soil Organic Carbon Stock in the project scenario is estimated as follows:

$$\Delta C_{SOC,t} = A \times \left(\left(C_{SOC,t} - C_{SOC,t-1} \right) \times \frac{44}{12} \right) \quad \text{(Equation 18)}$$

Where:

$\Delta C_{SOC,t}$	=	Change in carbon stock from soil organic carbon within the project boundary in year t; tCO_2e
A	=	Area; ha
$C_{SOC,t}$	=	Average carbon stock in soil organic carbon in the project scenario in year t; tC/ha
$C_{SOC,t-1}$	=	Average carbon stock in soil organic carbon in the project scenario in year t-1; tC/ha
$\frac{44}{12}$	=	Ratio of molecular weight of carbon dioxide to carbon; unitless

8.5 Leakage

Emissions from leakage, LK_t, are accounted using the latest version of SMD0002 Module for Estimating Leakage from ARR Activities.

8.6 Uncertainty

A precision target of a 90% or 95% confidence interval equal to or less than 20% or 30%, respectively, of the recorded value must be targeted. This is especially important in terms of project planning for measurement of carbon stocks where sufficient measurement plots should be included to achieve this precision level across the measured stocks.

Levels of uncertainty must be known for all aspects of baseline and project implementation and monitoring. Uncertainty will generally be known as the 90% or 95% confidence interval expressed as a percentage of the mean.

The quantification and consideration of uncertainty related to sample error are accounted for. Measurement error is dealt with by implementing quality assurance/quality control (QA/QC) procedures outlined in Section 9.2. Conservative parameters are applied in estimating emission sources from biomass burning and nitrogen fertilizer, with associated uncertainty being set at zero.

Uncertainty in area estimation is assumed to be zero and is addressed via complete (and accurate) GIS boundaries of the project area, and by applying QA/QC procedures. The performance benchmark is assumed to have zero uncertainty.

Uncertainty for project areas is calculated by propagating errors associated with estimates of included pools as:

$$Uncertainty_t = MIN\left(100\%, MAX\left(0, \left(\sum_{p=1}^{n}\left(U_{p,t=0} \times C_{p,t=0}\right)^2 + \sum_{p=1}^{n}\left(U_{p,t} \times C_{p,t}\right)^2\right)^{\frac{1}{2}} \times \left(\frac{1}{\Delta C_{WP-biomass,t} + \Delta C_{WP-SOC,t}}\right) - 10\%\right)\right)$$

(Equation 19)

Where:

$Uncertainty_t$	=	Uncertainty in cumulative removals through year t; %
$U_{p,t}$	=	Percentage uncertainty (expressed as 90 percent confidence interval as a percentage of the mean) in carbon stock estimate of pool p (representing woody biomass, non-woody biomass, dead wood, litter and SOC) in the project scenario in year t; %

$C_{p,t}$	=	Carbon stock estimate of pool p (e.g., woody biomass, non-woody biomass, dead wood, litter and SOC) in the project scenario in year t; tCO_2e
$\Delta C_{WP-biomass,t}$	=	Change in carbon stock in biomass carbon pools in the project scenario through year t; tC
$\Delta C_{WP-SOC,t}$	=	Change in carbon stock in SOC in the project scenario through year t; tC
t	=	1, 2, 3 …, t years elapsed since the project start date

A project is not eligible for crediting where the half-width of the two-sided 90 percent confidence interval exceeds 100 percent of the carbon dioxide removal estimate.

8.7 Net GHG Emission Removals

Net GHG emission removals are calculated deducting the leakage and project emissions from the total emission removals achieved within the project area. The non-permanence buffer must be calculated and deducted from NER_t as per the SOCIALCARBON Standard requirements.

$$NER_t = \left(TER_{WP,t} \times (1 - Uncertainty_t)\right) - PE_t - LK_t \quad \text{(Equation 20)}$$

Where:

NER_t	=	Net emission removals during monitoring period t; tCO_2e
$TER_{WP,t}$	=	Total emission removals during monitoring period t; tCO_2e
$Uncertainty_t$	=	Uncertainty in cumulative removals during monitoring period t; %
PE_t	=	Project emissions from biomass burning and fertilizer during monitoring period t; tCO_2e
LK_t	=	Leakage emissions during monitoring period t; tCO_2e

Total emission removals are calculated by combining the change in carbon stocks for the pools for the project areas exempt from a performance benchmark, and areas that must use a performance benchmark.

$$TER_{WP,t} = \left(\Delta C_{WP\_PB,t} \times (1 \times PB_t)\right) + \Delta C_{WP\_Exempt,t} \quad \text{(Equation 21)}$$

Where:

$TER_{WP,t}$	=	Total emission removals during monitoring period t; tCO_2e
$\Delta C_{WP\_PB,t}$	=	Project carbon stock change in areas where performance benchmark is required, during monitoring period t; %
PB_t	=	Performance benchmark for the monitoring interval ending in year t; %

$\Delta C_{WP\_Exempt,t}$ = Project carbon stock change in areas where performance benchmark is exempt, during monitoring period t; %

Where the project activity includes harvesting (in accordance with Section 4. Applicability Conditions), the project must also follow guidance in the current version of the SOCIALCARBON Standard for applying the long-term average GHG benefit as an upper limit on calculated carbon dioxide removals.

9. Monitoring

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied.

9.1 Data and Parameters Available at Validation

Data / Parameter	A
Data unit	ha
Description	Project area
Equations	12, 14, 16, 18
Source of data	Calculated from GIS data
Value applied	Project-specific
Justification of choice of data or description of measurement methods and procedures applied	Delineation of the project area may use a combination of GIS coverages, ground survey data with GPS, remote imagery (satellite or aerial photographs) or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of Data	Calculation of project emissions
Comments	The project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographic identification

Data / Parameter	R

Data unit	dimensionless
Description	Root to shoot ratio (i.e., ratio of belowground (root) biomass to aboveground biomass, per unit area or per stem)
Equations	13
Source of data	The selection of data sources should adhere to the following criteria: For project activities involving facilitated natural regeneration or encompassing more than two species in a single stand, the R value must be chosen from the following options, available in descending order of preference: a) Specific values for the forest type within the same ecoregion (defined at the biome level) or Holdridge life-zone as the project location; or b) Global values specific to the forest type (e.g., from Table 4.4 in Chapter 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories). Alternatively, in cases like monoculture plantations, the R value must be chosen from the following options, available in descending order of preference: c) Values specific to the forest type within the same ecoregion (defined at the biome level) or Holdridge life-zone as the project location; or d) Global values specific to the forest type (e.g., from Table 4.4 in Chapter 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories). It is important to note that when utilizing a global R ratio, it must have been developed from or validated with datasets that include direct measurements obtained through destructive sampling from within the same ecoregion or Holdridge life zone as the region where the project is located.
Value applied	Project-specific
Justification of choice of data or description of measurement methods and procedures applied	See source of data
Purpose of Data	Calculation of project emission removals
Comments	N/A

Data / Parameter	CF
Data unit	tC/t d.m.
Description	Carbon fraction of dry biomass
Equations	10, 15, 17
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value applied	0.47
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emission removals
Comments	None

Data / Parameter	$EF_{Ndirect}$
Data unit	t N_2O-N/t N applied
Description	Emission factor for direct nitrous oxide emissions from N additions due to synthetic fertilizers, organic amendments and crop residues.
Equations	3
Source of data	Table 11.1, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.01
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	$FRAC_{GASF}$
Data unit	Dimensionless
Description	Fraction of all synthetic N added to soils that volatilizes as NH_3 and NOx
Equations	7
Source of data	Table 11.3, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.11
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	$FRAC_{GASM}$
Data unit	Dimensionless
Description	Fraction of all organic N added to soils that volatilizes as NH_3 and NOx
Equations	7
Source of data	Table 11.3, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.21
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	EF_{NVolat}
Data unit	t N_2O-N/(t NH_3-N + NOx-N volatilized)
Description	Emission factor for nitrous oxide emissions from atmospheric deposition of N on soils and water surfaces
Equations	7
Source of data	Table 11.3, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.01
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	$FRAC_{LEACH}$
Data unit	Dimensionless
Description	Fraction of synthetic or organic N added to soils that is lost through leaching and runoff
Equations	3, 8
Source of data	Table 11.3, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.24
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	EF_{LEACH}
Data unit	t N_2O-N/t N leached and runoff
Description	Emission factor for nitrous oxide emissions from leaching and runoff
Equations	8
Source of data	Table 11.3, Chapter 11 in Volume 4 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value applied	0.011
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	COMF
Data unit	Dimensionless
Description	Combustion Factor
Equations	9
Source of data	Default mean values in Table 2.6 of IPCC 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories
Value applied	The combustion factor is selected based on vegetation type.
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	EF_g
Data unit	kg/t d.m. burned
Description	Emission factor for gas g
Equations	9
Source of data	Table 2.5, Chapter 2, Volume 4 of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (see Appendix 2: Emission factors for various types of burning for CH_4 and N_2O)
Value applied	Project-specific
Justification of choice of data or description of measurement methods and procedures applied	IPCC is a reputable source
Purpose of Data	Calculation of project emissions
Comments	None

Data / Parameter	GWP_g
Data unit	Dimensionless
Description	Global warming potential for gas g
Equations	3, 7 ,8 ,9
Source of data	Default factor from the latest IPCC Assessment Report
Value applied	Most recent IPCC Assessment Report
Justification of choice of data or description of measurement methods and procedures applied	See section 8.2.3
Purpose of Data	Calculation of project emissions
Comments	None

9.2 Data and Parameters Monitored

Data / Parameter:	$C_{Woody\text{-}AGB,t}$
Data unit:	tC / ha
Description:	Average aboveground woody biomass stocks in the project scenario in year t
Equations	13
Source of data:	Field measurement or remote sensing
Description of measurement methods and procedures to be applied:	Aboveground woody biomass must be measured either via plot-based sampling or remote sensing. Stratification may be employed to improve precision but is not required. Sample design need not be held constant across all monitoring and verification events. Plot-based sampling approaches (using area-based quantification) may be augmented using double or two-phase sampling approaches (e.g., 3P or ratio sampling). These approaches must include: 1) A complete census of an auxiliary variable (e.g., stocking index, see Appendix 1), and 2) A sample of direct field-based measurements used to determine the relationship (i.e., a ratio or regression) between aboveground woody biomass and the auxiliary variable. All sample measurements must: a) Be demonstrated to be unbiased and derived from representative sampling; b) Ensure accuracy through adherence to best practices and quality assurance/quality control (QA/QC) procedures (to be determined by the project proponent and outlined in standard operating procedures governing field data collection); and c) Apply fixed size thresholds on independent variables used in biomass estimation (e.g., diameter at breast height, diameter at root collar, height), to be maintained through the crediting period. Aboveground woody biomass of each sampled woody plant (e.g., tree, shrub) is estimated using published allometric equations applied to one or more measured attributes. For project activities involving facilitated natural regeneration or with more than two species in a single stand, equation(s) must be chosen from the following as available, listed in descending order of preference:

	i) Equations specific to the forest type within the same ecoregion (defined at the biome level14) or Holdridge life-zone15 as the region in which the project is located, or ii) Global equations specific to the forest type. Attributes (e.g., diameter at breast height, total height) incorporated as independent variables in allometric equations must be directly measured in the field applying established best practices, such as those found in: • Kershaw Jr, J. A., Ducey, M. J., Beers, T. W., & Husch, B. (2016). Forest mensuration. • John Wiley & Sons. Avery, T. E., & Burkhart, H. E. (2015). Forest measurements. Waveland Press. Measurement protocols must be detailed in standard operating procedures. Parameter tables for all attributes (e.g., diameter at breast height, total height) incorporated as independent variables in allometric equations must be included in the project description under “Data and Parameters Monitored.” Project proponents are permitted to utilize emerging technology (e.g., remote sensing) with known uncertainty to measure aboveground biomass stocks. These emerging technology approaches must be supported by peer-reviewed literature16 which validates their accuracy and uncertainty. Justification for the chosen approach shall be documented in the Project Description Document supplemented with appropriate evidence. Any uncertainty in the approach used must be discounted for. Models must at a minimum: • be publicly available from a reputable and recognized source (e.g., the model developer’s website, IPCC, or government agency); and • have been appropriately reviewed and tested under similar ecosystemic conditions by a recognized, competent organization, or an appropriate peer review group; and • have comprehensive and appropriate requirements for estimating uncertainty in keeping with IPCC or other appropriate guidance, and the model shall be calibrated by parameters such as geographic location and local climate data; and • apply conservative factors to discount for model uncertainty and shall use conservative assumptions and parameters that are likely to underestimate, rather than overestimate, the GHG emission reductions or removals. All parameters, data sources and assumptions applied by the emerging technology, alongside evidence of compliance with the

[14] https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-theworld?https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

[15] http://iridl.ldeo.columbia.edu/SOURCES/.ECOSYSTEMS/.Holdridge/present+.life-zone/downloadsGeoTiff.html

[16] The literature must be in a journal indexed in the Web of Science: Science Citation Index (SCI: available at https://mjl.clarivate.com).

	minimum requirements outlined above, must be documented in the Project Description Document.
Frequency of monitoring/recording:	At every monitoring period. At least every 3 years.
QA/QC procedures to be applied:	To be determined by the project proponent and outlined in standard operating procedures governing field data collection and utilization of emerging technologies.
Purpose of data:	Calculation of project removals
Calculation method:	Calculated as the average of sample measurements
Comments:	None

Data / Parameter:	$Uncertainty_t$
Data unit:	Percent
Description:	Percentage uncertainty (expressed as 90 percent confidence interval as a percentage of the mean) in carbon stock estimate of pool p in the project scenario in year t
Equations	19, 20
Source of data:	Calculations from sampled field measurements / emerging technology-based measurements
Description of measurement methods and procedures to be applied:	Uncertainty in pools derived from field measurements with 90 percent confidence interval calculated as the standard error of the averaged plot measurement multiplied by the t value for the 90 percent confidence level. Where double or two-phase sampling approaches are employed for aboveground woody biomass, parameter $U_{p,woody,t}$ is represented by error in the relationship (ratio or regression) between the auxiliary variable and woody biomass, referencing the 90 percent confidence interval of the ratio or 1.645 times the root mean squared error of the regression. Sample error in the auxiliary variable is not treated, because it must be subject to a complete census (see parameter table for $C_{woody\text{-}AGB,t}$ above). Where double or two-phase sampling approaches are employed for litter (i.e., where subsampling is employed to estimate the dry-to-green weight ratio that is then applied to a sample estimate of green weight (see parameter tables for $DM_{Litter,t}$), parameters $U_{p,Litter,t}$ are

	calculated by propagating sample error of the green weight estimate and sample error of the estimate of dry-to-green weight ratio. Project proponents are permitted to utilize emerging technology (e.g., remote sensing) with known uncertainty to measure aboveground biomass stocks. These emerging technology approaches must be supported by peer-reviewed literature[17] which validates their accuracy and uncertainty. Justification for the chosen approach shall be documented in the Project Description Document supplemented with appropriate evidence. Any uncertainty in the approach used must be discounted for. Models must at a minimum: • be publicly available from a reputable and recognized source (e.g., the model developer's website, IPCC, or government agency); and • have been appropriately reviewed and tested under similar ecosystemic conditions by a recognized, competent organization, or an appropriate peer review group; and • have comprehensive and appropriate requirements for estimating uncertainty in keeping with IPCC or other appropriate guidance, and the model shall be calibrated by parameters such as geographic location and local climate data; and • apply conservative factors to discount for model uncertainty and shall use conservative assumptions and parameters that are likely to underestimate, rather than overestimate, the GHG emission reductions or removals. All parameters, data sources and assumptions applied by the emerging technology, alongside evidence of compliance with the minimum requirements outlined above, must be documented in the Project Description Document.
Frequency of monitoring/recording:	At every monitoring period
QA/QC procedures to be applied:	See "Description of measurement methods and procedures to be applied"
Purpose of data:	Calculation of project removals
Calculation method:	Confidence interval calculated by applying unbiased estimators appropriate to sample design. For examples, see Cochran, W.G. (1977). Sampling techniques. John Wiley & Sons.
Comments:	Pools p include woody biomass, non-woody biomass, dead wood, litter and SOC.

[17] The literature must be in a journal indexed in the Web of Science: Science Citation Index (SCI: available at https://mjl.clarivate.com).

Data / Parameter:	$A_{burn,t}$
Data unit:	ha
Description:	Area burned in the monitoring interval ending in year t
Equations	9
Source of data:	Calculated from GIS data
Description of measurement methods and procedures to be applied:	Delineation of the area burned may use a combination of remote imagery (satellite or aerial photographs) or ground survey data with GPS.
Frequency of monitoring/recording:	At every monitoring period
QA/QC procedures to be applied:	Any imagery used must be geo-registered referencing corner points, clear landmarks or other intersection points. All geo-coordinates or imagery must be publicly accessible to support third-party verification.
Purpose of data:	Calculation of project emissions
Calculation method:	Calculated using GIS
Comments:	None

Data / Parameter:	$M_{SF,t}$
Data unit:	t fertilizer
Description:	Mass of N-containing synthetic fertilizer applied in the project scenario in the monitoring interval ending in year t
Equations	4
Source of data:	Mass of synthetic fertilizer applied in the project, as recorded in land management records
Description of measurement methods	Information is monitored via direct consultation with, and substantiated with a written attestation from, the local land manager.

and procedures to be applied:	
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	Any quantitative information (e.g., discrete or continuous numeric variables) on management practices must be supported by one or more forms of documented evidence pertaining to the project and relevant monitoring period (e.g., management logs, receipts or invoices).
Purpose of data:	Calculation of project emissions
Calculation method:	Not calculated
Comments:	None

Data / Parameter:	$M_{OF,t}$
Data unit:	t fertilizer
Description:	Mass of N-containing organic fertilizer applied in the project scenario in the monitoring interval ending in year t
Equations	5
Source of data:	Mass of organic fertilizer applied in the project, as recorded in land management records
Description of measurement methods and procedures to be applied:	Information is monitored via direct consultation with, and substantiated with a written attestation from, the local land manager.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	Any quantitative information (e.g., discrete or continuous numeric variables) on management practices must be supported by one or more forms of documented evidence pertaining to the project and relevant monitoring period (e.g., management logs, receipts or invoices).

Purpose of data:	Calculation of project emissions
Calculation method:	Not calculated
Comments:	None

Data / Parameter:	$NC_{SF,t}$
Data unit:	t N/t fertilizer
Description:	N content of synthetic fertilizer applied in the project in year t
Equations	3, 4
Source of data:	N content is determined following fertilizer manufacturer's specifications
Description of measurement methods and procedures to be applied:	Not directly measured. Recorded from fertilizer manufacturer's specifications and evidenced in management records, receipts or invoices.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	Any quantitative information on management practices must be supported by one or more forms of documented evidence pertaining to the project area and relevant monitoring period (e.g., management logs, receipts or invoices).
Purpose of data:	Calculation of project emissions
Calculation method:	Not calculated
Comments:	None

Data / Parameter:	$NC_{OF,t}$
Data unit:	t N/t fertilizer
Description:	N content of organic fertilizer applied in the project in year t

Equations	5
Source of data:	Published or peer-reviewed data must be used, with preference for more recent data from the project country.
Description of measurement methods and procedures to be applied:	Not directly measured.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	Data referenced must be published or peer-reviewed.
Purpose of data:	Calculation of project emissions
Calculation method:	Not calculated
Comments:	None

Data / Parameter:	$B_{SDW,t}$
Data unit:	t d.m/ha
Description:	Average biomass of standing dead wood in year t
Equations	15
Source of data:	Field measurements
Description of measurement methods and procedures to be applied:	Standing dead wood is measured via plot-based sampling. Stratification may be employed to improve precision but is not required. Sample design need not be held constant across all monitoring and verification events. Sample measurements must: 1) Be demonstrated to be unbiased and derived from representative sampling; 2) Ensure accuracy through adherence to best practices and quality assurance/quality control (QA/QC) procedures (to be determined by the project proponent and outlined in standard operating procedures governing field data collection); and 3) Apply fixed size thresholds.

	For each standing dead woody plant (e.g., tree, shrub), stem volume must be estimated using published allometric equations applied to one or more measured attributes. For project activities involving facilitated natural regeneration or with more than two species in a single stand, equation(s) must be chosen from the following as available, listed in descending order of preference: a) Equations specific to the forest type within the same ecoregion (defined at the biome level[18] or Holdridge life-zone[19] as the region in which the project is located, or b) Global equations specific to the forest type. Note that standing dead wood is restricted here to visible aboveground stem (bole) biomass, and must discount any missing portions of the stem (e.g., referencing visible break height in volume estimation). Attributes (e.g., diameter at breast height, total height) incorporated as independent variables in allometric equations must be directly measured in the field applying established best practices, such as those found in: • Kershaw Jr, J. A., Ducey, M. J., Beers, T. W., & Husch, B. (2016). Forest mensuration. • John Wiley & Sons. Avery, T. E., & Burkhart, H. E. (2015). Forest measurements. Waveland Press. Measurement protocols must be detailed in standard operating procedures. Parameter tables for all attributes (e.g., diameter at breast height, total height) incorporated as independent variables in allometric equations must be included in the project description under "Data and Parameters Monitored." Biomass of standing dead wood must be estimated from sampled volumes using published wood densities (specific to the species, genus, family or forest type as available, in descending order of preference) and density reduction factors referencing decomposition states (e.g., procedures per Harmon et al., 2011).
Frequency of monitoring/recording:	At every monitoring period
QA/QC procedures to be applied:	See "Description of measurement methods and procedures to be applied

[18] https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-theworld?https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

[19] http://iridl.ldeo.columbia.edu/SOURCES/.ECOSYSTEMS/.Holdridge/present+.life-zone/downloadsGeoTiff.html

Purpose of data:	Calculation of project emission removals
Calculation method:	Calculated as the average of sample measurements
Comments:	None

Data / Parameter:	$B_{LDW,t}$
Data unit:	t d.m/ha
Description:	Average biomass of lying dead wood in year t
Equations	15
Source of data:	Field measurements
Description of measurement methods and procedures to be applied:	Standing dead wood is measured via plot-based sampling. Stratification may be employed to improve precision but is not required. Sample design need not be held constant across all monitoring and verification events. Sample measurements must: 1) Be demonstrated to be unbiased and derived from representative sampling; 2) Ensure accuracy through adherence to best practices and quality assurance/quality control (QA/QC) procedures (to be determined by the project proponent and outlined in standard operating procedures governing field data collection); and 3) Apply fixed size thresholds. Protocols must be detailed in standard operating procedures and parameter tables under "Data and Parameters Monitored" for all lying dead wood attributes (e.g., cross-sectional diameter, length) measured and recorded. Biomass of lying dead wood must be estimated from sampled volumes using published wood densities (specific to the species, genus, family or forest type as available, in descending order of preference) and density reduction factors referencing decomposition states (e.g., procedures per Harmon et al., 2011).
Frequency of monitoring/recording:	At every monitoring period
QA/QC procedures to be applied:	See "Description of measurement methods and procedures to be applied

Purpose of data:	Calculation of project emission removals
Calculation method:	Calculated as the average of sample measurements
Comments:	None

Data / Parameter:	$DM_{Litter,t}$
Data unit:	t d.m/ha
Description:	Average litter dry mass per hectare in the project scenario in year t
Equations	17
Source of data:	Field measurements
Description of measurement methods and procedures to be applied:	Litter is assessed using destructive sampling, and while stratification can be applied to enhance precision, it is not mandatory. The sample design is not required to remain consistent across all monitoring and verification events. The collection of litter (defined as dead organic surface material with a diameter of less than 10 cm) involves gathering samples within fixed-area sampling frames. These samples are harvested at ground level, and subsequent to collection, they are dried at 70 ºC until reaching a constant weight to determine dry weight biomass. In instances where the sample bulk is excessive, both the green weight of the total sample and that of a representative sub-sample are documented in the field. The sub-sample is then taken to the laboratory for moisture content determination (i.e., oven dry weight to green weight ratio). From this information, the dry weight biomass of the total green weight recorded in the field is estimated. Additional guidance is available in the IPCC (2003) Good Practice Guidance for Land-Use, Land-Use Change, and Forestry (GPG-LULUCF).
Frequency of monitoring/recording:	At every monitoring period
QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QC procedures available from published handbooks, such as

	those published by FAO and available on the FAO Soils Portal[20] or from the IPCC (2003) GPG LULUCF is recommended.
Purpose of data:	Calculation of project removals
Calculation method:	Calculated as the average of sample measurements
Comments:	Note that where subsampling is employed to determine a dry-to-green weight ratio, uncertainty is calculated by treating the sample as a double sample (see parameter $U_{p,t}$).

Data / Parameter:	$C_{SOC,t}$
Data unit:	tC/ha
Description:	Average soil organic carbon (SOC) stock in year t
Equations	18
Source of data:	Field measurements
Description of measurement methods and procedures to be applied:	Measured SOC must be determined from samples collected from sample plots located within the project area. Stratification may be employed to improve precision but is not required. Sample design need not be held constant across all monitoring and verification events. All organic material (e.g., living plants, litter) must be cleared from the soil surface prior to soil sampling. Soil must be sampled to a minimum depth of 30 cm. SOC stocks must be estimated from measurements of both SOC content and bulk density taken at the same time. Estimates generated must: 1) Be demonstrated to be unbiased and derived from representative sampling; and 2) Ensure accuracy through employment of quality assurance/quality control (QA/QC) procedures (to be determined by the project proponent and outlined in the monitoring plan). Soil sampling must follow established best practices, such as those found in:

[20] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

	• Cline, M. G. (1944). Principles of soil sampling. Soil Science, 58(4), 275– 288. • Petersen, R. G., & Calvin, L. D. (1986). Sampling. In A. Klute (Ed.), Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods. Soil Science Society of America and American Society of Agronomy. Re-measurement of soil carbon (after t = 0) must use equivalent soil mass procedures (see Wendt & Hauser, 2013). Determination of percent SOC must follow established laboratory procedures, such as those found in: • Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. In A. L. Page et al. (Eds.) Methods of Soil Analysis. Part 3 Chemical methods. American Society of Agronomy and Soil Science Society of America. • Schumacher, B. A. (2002). Methods for the determination of total organic carbon (TOC) in soils and sediments. U.S. Environmental Protection Agency, EPA/600/R-02/069 (NTIS PB2003-100822), or other regionally appropriate sources such as the European Environment Agency. Procedures for SOC and bulk density (including all sample handling, preparation for analysis and analysis techniques) must be thoroughly described in field sampling protocols and in parameter tables under "Data and Parameters Monitored."
Frequency of monitoring/recording:	At time t = 0 and subsequently at every verification (every five years or more frequently). SOC may be measured less frequently than other pools (but not less frequently than every 5 years) and reported as zero during intervening monitoring and verification events where soil disturbance from the project activity (i.e., from site preparation): a) occurs only once during the project crediting period (i.e., at site preparation); or b) does not entail soil inversion beyond a depth of 25 cm (e.g., as would occur with a moldboard plow).
QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QC procedures available from published hand-books, such as those published by FAO and available on the FAO Soils Portal[21] or from the IPCC (2003) GPG LULUCF is recommended.
Purpose of data:	Calculation of project removals

[21] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

Calculation method:	Calculated as the average of sample measurements
Comments:	None

9.3 Description of the Monitoring Plan

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 9.2. The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken, and the technical requirements therein;
- Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and quantification approaches (performance benchmarking or not);
- Data to be collected and data collection techniques, including data used in monitoring of the performance benchmark, documented in a standard operating procedure for field data collection. Sample designs must be specified (clearly delineate the sample population, justify sampling intensities, selection of sample units and sampling stages, where applicable) and un-biased estimators of population parameters identified that are applied in calculations;
- Parameters to be measured, including parameter tables for all directly measured woody plant attributes (e.g., diameter at breast height, total height) incorporated as independent variables in allometric equations;
- All allometric models (for aboveground biomass) and root-to-shoot ratios (for belowground biomass) used in quantifying carbon stocks must be specifically identified. Project proponents must articulate the appropriateness and conservativeness of their choice of allometric models and other scaling factors based on considerations including sample size, tree species specificity, destructive sample proximity, and size classes included in destructive sample;
- Anticipated frequency of monitoring, including anticipated definition of “year”;
- Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection and screen for, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate;
- A full description of the stocking index, and the process to derive it (reference to the database is insufficient);
- Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of monitoring process, including QA/QC data, must be archived electronically and be kept at least for two years after the end of the last project crediting period;
- Roles, responsibilities and capacity of monitoring team and management; and
- Project proponents must include in their project description and monitoring reports a discussion of all possible sources of bias in estimation, efforts taken to eliminate bias, and any quantitative or qualitative indications of the absence of bias.

9.3.1 Database Requirements for Project and Control Plots

For projects using the performance benchmark approach, a database must be maintained where datasets related to plots are reposited and made publicly accessible. The database must include, at a minimum:

1) A description of the stocking index and the process to derive it;
2) A list of project plots including unique IDs, locations, size and configuration and time series of stocking index values from time t = 0 to time t.
3) A list of control plots including unique IDs (referencing unique ID of corresponding project plot to which they are matched), locations, size and configuration, weights and time series of stocking index values from time t = 0 to time t; and
4) Remote sensing datasets and time stamps used to derive stocking index values.

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Appendix 1: Performance Benchmarking

The project's performance benchmark must be updated at each verification.

Purpose

Performance Benchmarking serves the purpose of evaluating the most realistic baseline scenario for land areas within the project boundary that could undergo passive restoration. This scenario is depicted by the typical growth of carbon stocks, observed on representative control plots located outside of any registered AFOLU project area. Specifically, the baseline scenario reflects the expected changes in above-ground biomass on these control plots. This method is considered the most realistic because remote sensing provides continuous and measurable observations of aboveground biomass changes, enabling real-time comparisons between project areas and baselines.

The performance benchmark represents the expected changes in vegetation cover under business-as-usual conditions. It is determined by the ratio of the average change in the stocking index (SI) of control plots to that of project plots. Control plots are carefully selected to match the project area based on similar biophysical, social, and political conditions, as well as historic stock trends (details below). The stocking index of control plots is monitored using remote sensing and does not require direct field measurement. The baseline is recalibrated at each verification period using an updated performance benchmark.

The application of the performance benchmark, as described below, effectively prevents the crediting of project activities that would likely occur even without carbon incentives, based on comparative outcomes i.e. passive restoration would have occurred on the land without carbon incentives. It also ensures that credited projects demonstrate performance improvements compared to the business-as-usual case, represented by the crediting baseline.

It's important to note that all project and control plots referenced in the appendix are assessed using remote sensing and will henceforth be referred to as "project plots" and "control plots."

Performance Benchmark

The performance benchmark is established by comparing the average rate of increase in the stocking index (SI) between project and control plots. Equation (A4) is utilized to calculate the performance benchmark for both demonstrating additionality and determining the crediting baseline. Equation 21 applies this benchmark specifically for the crediting baseline. Each project area, or in the case of grouped projects, each annual cohort of instances, has its own performance benchmark. These benchmarks are monitored ex post, meaning they are dynamic and subject to change over time.

The method for selecting control plots, as described below, follows a matching approach commonly used in environmental impact evaluation (Ferraro & Hanauer, 2014). This matching approach aims to produce robust estimates of impact for sample populations of matched pairs (controls and treatments), rather than exact matches for individual land parcels.

An ex-ante estimate of the performance benchmark must be calculated by referencing a value of $\Delta SI_{control,t}$, using the stocking indices for the historic period t=-10 to t=0 for the selected control plots (derived above).

The assessment of plots using remote sensing does not involve direct estimation and reporting of carbon stocks. Remote sensing is solely used to estimate the relative stock change between control and project plots. Accounting for emission reductions and removals is addressed in Section 8 and relies on direct field measurement.

Procedure to Define the Performance Benchmark

The process of setting up the performance benchmark should be clearly outlined in the project description with enough detail to enable replication and validation. Every step outlined below must be thoroughly documented as part of the monitoring plan for both project and control plots, as outlined in section 9.2 of the methodology.

Overview of Establishing the Performance Benchmark:

1) Starting at time t=0, or at time t > 0 where initial stock measurements occurred after the project start date. Select project plots via representative sampling.
2) For each project plot, select matched control plots:
   a) Delineate the donor pool using maps of categorical variables matching the project plot.
   b) Evaluate continuous matching covariates (including the historical trend in stocking index) on prospective control plots.
   c) Select k control plots most closely matching the project plot.
3) For the sample population of matched project and control plots, evaluate match quality and finalize matching.

Assessment of the Performance Benchmark at each monitoring event:

1) Monitor stocking index on project and control plots.
2) Derive slopes for accumulated time series (from time t = 0 to time t) of stocking indices estimated across the sample populations of project and control plots.
3) Calculate performance benchmark.

Step 1: Select project plots

The following must be performed for each annual cohort separately.

1) Divide the entire project annual cohort area into contiguous, non-overlapping units (project plots) ranging from 0.09 hectares (30 × 30 m) to 10 hectares in area. At least 75 percent of each

unit must be within the project area boundary. Project plots may be represented by individual pixels or aggregates of pixels.

2) Select a representative sample of n = 30 or more project plots, via random or systematic, stratified, or un-stratified sampling.

Step 2: Select control plots for each project plot

1) **Select donor pool area**

   Define donor pool area from within which control plots may be sourced, applying criteria in Table 4.

   The process to determine the eligible control area is implemented with a series of GIS overlays. The project may include other spatially explicit, categorical drivers of carbon regeneration or reforestation (e.g., land cover classifications), provided their inclusion is justified on a theoretically sound or empirically demonstrated basis (e.g., peer-reviewed study). Any geospatial datasets included must have resolution no coarser than 30 x 30 meters.

Table 4: Required factors and source data to delineate donor pool area, evaluated for time t = 0. Time variant geospatial layers used must be current as of t = 0, ±5 years

Factor	Procedure and data source (GIS layer)
Ecoregion	The donor pool area must exclude any areas not within the same ecoregion (biome level) as the project.
Policy Environment	The donor pool area should not include any regions within the jurisdictional boundary (as defined previously) where there are existing government-funded programs offering incentives for tree planting that are distinct from those in the project area. These programs refer to currently funded and implemented national or sub-national government policies or initiatives providing monetary incentives for tree planting, such as the USDA Conservation Reserve Program.
Outside any registered AFOLU project	Optionally, and as available, the donor pool area may exclude boundaries of any AFOLU projects registered under a carbon offset program. Source: kml files from project registries (e.g., SOCIALCARBON registry)
Land Tenure	The donor pool must include all land tenure classifications found within the project area, ensuring that no areas with differing land tenure classifications are included. Land tenure classifications should be obtained from published or official government sources. At the very least, the classification should differentiate between public and private lands. Where more detailed classifications are

	available (such as indigenous reserves, concessions, or private industrial lands), these may be utilized. The source of these classifications shall also be a published or an official government source.
Proximity from project	Exclude areas beyond a 100 km radius of the centroid of the project plot.

2) Evaluate project plots

After delineating the donor pool area using the criteria outlined in Table 4, it is partitioned into distinct units, each with a size that does not exceed ±20 percent of the average size of project plots.

To assess the historical and initial conditions of the stocking index (SI), a time series analysis is conducted for representative control and project plots, as specified in Table 5. This analysis involves running a regression for the SI of each control and project plot over time, incorporating a minimum of three time points.

- between t=-10 and t=-8
- between t=-8 and t=-1
- at t=0

Table 5: Required covariates for matching control plots to project plots (detailed guidance on each covariate provided in "Data and Parameters Monitored" below).

Matching Covariate	Description
$SI_{t=0}$, $SI_{t=-10}$, etc.	The stocking indices should be gathered from at least three time points within the historical period, which covers 8–10 years leading up to the project's initiation. This dataset should include values from the start of the historical period (not earlier than t = −10 and no later than t = −8) as well as the time at t = 0.

For each control plot, calculate a multivariate distance metric, MD (e.g., Euclidean distance, Mahalanobis distance), across the vector of covariates (i.e., the minimum three time points referenced above), relative to the project plot.

3) Select control plots

To align control plots with project plots, employ a k-nearest neighbour optimal matching approach without replacement. This means each control plot is matched to a single project sample plot. The project proponent chooses the number of control plots matched to each project plot, denoted as k, and this value remains constant for each match throughout the project's lifetime (e.g., if k=5 for project plot A, it must consistently be 5 for the project's duration).

Select k control plots with the lowest multivariate distance metric values, and calculate relative weights that are proportional to the inverse of the multivariate distance metric values. Ensure that these weights sum to 1, as per Equation (A1).

$$W_{Control,i,j} = \frac{e^{-MD_{i,j}}}{\sum_{j=1}^{n_{i,j}} e^{-MD_{i,j}}}$$ (Equation A1)

Where:

$W_{Control,i,j}$	=	Weight of control plot j matched to project plot I; value between 0 and 1; dimensionless
$MD_{i,j}$	=	Multivariate distance of control plot j relative to project plot I; dimensionless
$n_{i,j}$	=	Number of control plots matched to project plot I; equal to k at project start date

Step 3: Evaluate match quality and finalize matching

For the sample population of matched pairs (project plots and matched sets of control plots), evaluate match quality and finalize matching.

For each included matching covariate x, calculate the standardized difference of means (SDM) as:

$$SDM = \frac{ABS\left(\bar{x}_{wp,x} - \bar{x}_{bsl,x}\right)}{\sqrt{\left(\frac{\sigma^2{}_{wp,x} - \sigma^2{}_{bsl,x}}{2}\right)}}$$ (Equation A2)

Where:

SDM	=	Standardized difference of means
$\bar{x}_{wp,x}$	=	Mean value of covariate x in the population of project plots
$\bar{x}_{bsl,x}$	=	Mean value of weighted sums of covariate x in the population of matched sets of control plots
$\sigma^2{}_{wp,x}$	=	Standard deviation of covariate x in the population of project plots
$\sigma^2{}_{bsl,x}$	=	Standard deviation of covariate x in the population of control plots

The match results are considered valid when the standard deviation of the difference in means (SDM) for each covariate is 0.25 or less. If the overall match is deemed valid, the selection of control plots and their corresponding weights are finalized. The UTM coordinates are recorded and remain fixed throughout the crediting period. If the overall match is not considered valid, Steps 1, 2, and 3 are repeated after:

a) Progressively expanding the radius of the donor pool in 100 km increments, and/or
b) Decreasing the k value for all project plots, until a valid overall match is achieved.

Step 4: Monitor control and project plots

The performance benchmark is derived from monitoring stocking index, SI, in control and project plots. In each control and project plot, assess and record initial SI value.

At each monitoring event, remove any control plots deemed invalid due to their location in areas no longer matching the project area in terms of being either:

a) Subject to any operating subnational government-funded program providing incentives for tree planting, implemented during the evaluation period, to which the project area is not subject; or
b) Within the boundaries of any AFOLU projects registered under a carbon offset program (optional).

If a control plot is considered invalid, it is removed and replaced with another plot from the donor pool selected in Step 2. The weights of the control plots must be recalculated to ensure they sum up to 1. For every remaining valid control and project plot, reassess the stocking index (SI) using the most recent imagery available, adhering to the temporal constraints outlined in the SI parameter table for guidance on sourcing imagery.

Step 5. Derive and evaluate slopes for time series of stocking indices

Compile the accumulated time series data of $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ values from time t = 0 to time t, estimated across the sample populations of project and control plots. The determination of the stocking index (SI) for the monitoring interval should involve a minimum of three time steps: t, t=0, and at least one time point between t and t=0.

For inclusion in the dataset, SI values must be accessible at time t for project plot i and all its matched control plots i,j. If SI values for plots within a matched set are unavailable at time t (e.g., due to cloud cover or temporary sensor issues), the matched set of project and control plots (i) should not be utilized in deriving $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ at each time t. A minimum of n=30 project plots is necessary to ensure a representative sample of the area.

The rate of increase in stocking index in both control and project plots, $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ is computed as the slope of the weighted linear regression of the accumulated time series of SI values for the respective population of plots. Refer to Example 1 below for further clarification.

Weights of SI values for control plots in the time series are calculated as:

$$W_{control,i,j,t} = W_{control,i,j} \times \frac{1}{\sum_{t=0}^{t} n\_rs_t}$$ (Equation A3)

Where:

$W_{control,i,j,t}$	=	Weight of control plot j matched to project plot i at time t; dimensionless
$W_{control,i,j}$	=	Weight of control plot j matched to project plot i (value between 0 and 1; dimensionless
n_rs_t	=	Number of project plots and matched control plots (i,j) with values assessed at time t

Weights of SI values for project plots in the time series are calculated as:

$$W_{wp,i,t} = \frac{1}{\sum_{t=0}^{t} n\_rs_t}$$ (Equation A4)

Where:

$W_{wp,i,t}$	=	Weight of project plot i at time t; dimensionless
n_rs_t	=	Number of project plots and matched control plots (i,j) with values assessed at time t

The significance of the difference between $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ is evaluated with a Z test as follows:

$$z = \frac{\Delta \mathrm{SI}_{\mathrm{wp,t}} + \Delta \mathrm{SI}_{\mathrm{control,t}}}{\sqrt{SE^2_{\Delta SI\_wp,t} + SE^2_{\Delta SI\_control,t}}}$$ (Equation A5)

Where:

z	=	Z value (unitless)
$\Delta \mathrm{SI}_{\mathrm{wp,t}}$	=	Average annual increase (slope) in stocking index SI in project plots through time t
$\Delta \mathrm{SI}_{\mathrm{control,t}}$	=	Average annual increase (slope) in stocking index SI in control plots through time t
$SE^2_{\Delta SI\_wp,t}$	=	Squared standard error of the average annual increase (slope) in stocking index SI in project plots through time t
$SE^2_{\Delta SI\_control,t}$	=	Squared standard error of the average annual increase (slope) in stocking index, SI, in control plots through time t
t	=	1, 2, 3, …, t years elapsed since the project start date

Where the absolute value of Z is equal to or exceeds 1.96, parameters $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ are deemed significantly different.

Step 6: Derive performance benchmark

Where parameters $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ are not deemed significantly different (Z < 1.96, see above), PB_t is set equal to 1.

Where parameters $\Delta SI_{control,t}$ and $\Delta SI_{wp,t}$ are deemed significantly different (Z ≥ 1.96, see above), calculate the performance benchmark as the ratio of average change in SI in control plots to average change in SI in the project area (Equation (A6)). Where the slope coefficient of the control plots, $\Delta SI_{control,t}$, is insignificant (P > 0.05) or less than zero, $\Delta SI_{control,t}$ is set equal to zero in Equation (A6).

$$PB_t = \Delta SI_{control,t} \times \frac{1}{\Delta SI_{wp,t}} \qquad \text{(Equation A6)}$$

Where:

PB_t	=	Performance benchmark for the monitoring interval ending at year t; dimensionless
$\Delta SI_{wp,t}$	=	Average annual increase (slope) in stocking index SI in project plots through time t
$\Delta SI_{control,t}$	=	Average annual increase (slope) in stocking index SI in control plots through time t

Example 1: Simplified performance benchmark with one project plot and 10 matched control plots[22]

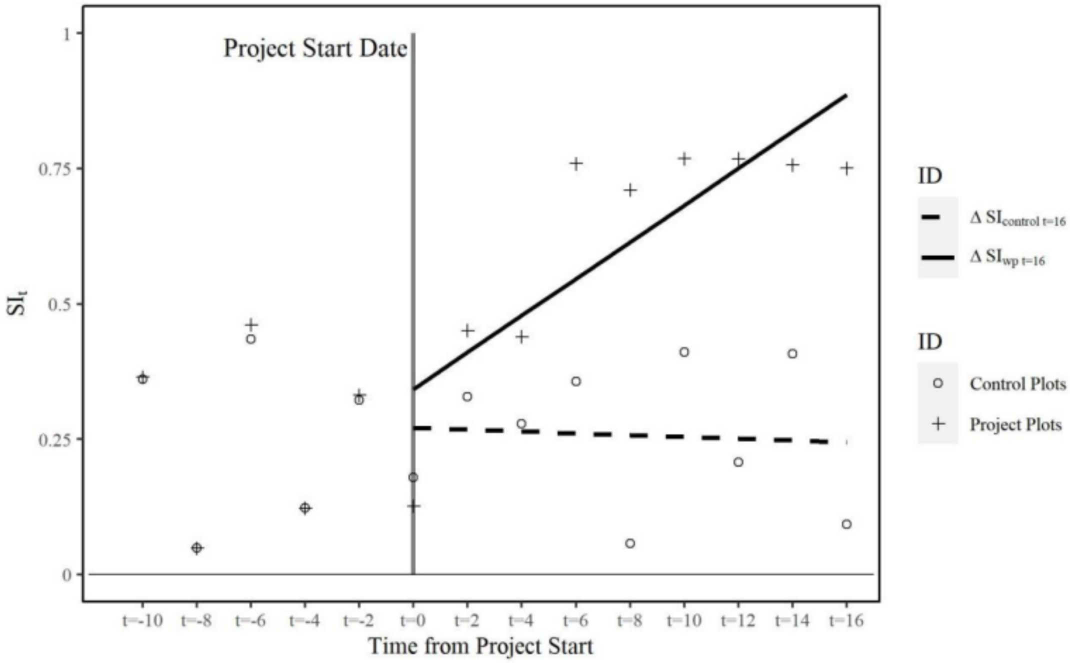
T	*Control Plot I,j*	$W_{control,i,j,t}$	$SI_{control,i,j,t}$	$W_{control,i,j,t=3}$
0	1_1	0.20	0.09	0.10
0	1_2	0.17	0.05	0.08
0	1_3	0.14	0.01	0.07
0	1_4	0.11	0.05	0.06
0	1_5	0.09	0.06	0.05
0	1_6	0.09	0	0.04
0	1_7	0.08	0.02	0.04
0	1_8	0.06	0.2	0.03
0	1_9	0.05	0.1	0.03
0	1_10	0.01	0.09	0.00
5	1_1	0.20	0.07	0.10
5	1_2	0.17	0.23	0.08
5	1_3	0.14	0.15	0.07

[22] Example adapted from VCS Methodology VM0047 v1.0 pages 62 - 64

5	1_4	0.11	0.21	0.06
5	1_5	0.09	0.05	0.05
5	1_6	0.09	0.19	0.04
5	1_7	0.08	0.15	0.04
5	1_8	0.06	0.14	0.03
5	1_9	0.05	0.21	0.03
5	1_10	0.01	0.18	0.00
		$\Delta SI_{control,i,j,t=5}$	0.02	Fitted weighted least squares

T	Project plot i	$W_{wp,i,t}$	$SI_{wp,i,t}$
0	1	1	0.06
5	1	1	0.91
		$\mathbf{\Delta SI_{wp,t}}$	0.17
		$\mathbf{PB_t}$	12%

Figure 2: Example of matching (ex-ante) and monitoring (ex-post) control plots (n = 100) and project plots (n = 100). Each data point represents the mean SI evaluated at time t. Here, $\Delta SI_{wp,t=16}$ = 0.02, and $\Delta SI_{control,t=16}$ = −0.0008 (not significantly different) from $PB_{t=16}$ = 0



With project: steady growth				Control: agriculture with fallow cycle			
T	$SI_{wp,t}$	$\Delta SI_{wp,t}$		T	$SI_{control,t}$	$\Delta SI_{control,t}$	PB_t
0	0.00			0	0.00		
1	0.03	0.03		1	0.00	0.00	0%
2	0.09	0.06		2	0.01	0.01	17%
3	0.15	0.06		3	0.02	0.01	17%
4	0.20	0.05		4	0.03	0.01	20%
5	0.26	0.06		5	0.00	0.00	0%
6	0.32	0.06		6	0.00	0.00	0%
7	0.38	0.06		7	0.01	0.00	0%
8	0.43	0.05		8	0.02	0.00	0%
9	0.47	0.04		9	0.03	0.00	0%
10	0.52	0.05		10	0.00	0.00	0%
11	0.56	0.03		11	0.00	0.00	0%
12	0.60	0.04		12	0.01	0.00	0%
13	0.63	0.03		13	0.02	0.00	0%
14	0.67	0.04		14	0.03	0.00	0%
15	0.70	0.03		15	0.00	0.00	0%
16	0.72	0.02		16	0.00	0.00	0%
17	0.75	0.03		17	0.01	0.00	0%
18	0.77	0.02		18	0.02	0.00	0%
19	0.79	0.02		19	0.03	0.00	0%
20	0.81	0.02		20	0.00	0.00	0%

Data and Parameters Monitored

Data / Parameter:	$SI_{control,t}$ and $SI_{wp,t}$
Data unit:	Unspecified
Description:	Stocking index in scenario (control plot j or project plot i) at time t
Equations	A5
Source of data:	SI is an unspecified remote sensing metric that has demonstrated correlation with terrestrial aboveground carbon stocks (e.g., normalized difference fraction index[23] from Landsat imagery, average canopy height derived from LiDAR or percentage canopy cover interpreted from aerial imagery). Variability due to seasonality must be minimized (e.g., by setting a target data collection period at the project start and collecting all

[23] Souza Jr, C. M., Roberts, D. A., and & Cochrane, M. A., (2005). Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment, 98(2–3):329–-343. https://doi.org/10.1016/j.rse.2005.07.013

	monitoring imagery from within that period). Target period should coincide with minimal seasonal phenological variation, and where passive remote sensors are employed this should coincide with months of lowest cloud cover. Spatial scale: Divide the entire project area into polygons from 0.09 hectares (30 × 30 m) to 10 hectares in area. Polygons must be of equal size with at least 75 percent of each polygon located within the project area boundary. project plots may be represented by individual pixels or aggregates of pixels.
Description of measurement methods and procedures to be applied:	See section "QA/QC procedures to be applied"
Frequency of monitoring/recording:	At least annually
QA/QC procedures to be applied:	The remote sensing metric applied must: 1. Have significant correlation with terrestrial carbon stocks, at least with aboveground biomass, that has been previously substantiated with published or peer-reviewed studies.[24] 2. Be validated with direct measurements from the project region (collected from within the project ecoregion; ecoregion defined at the biome level[25]). Processing and analysis of remote sensing data must apply established best practices, such as those found in: Global Forest Observations Initiative (2016). Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and guidance from the Global Forest Observations Initiative, edition 2.0. U.N. Food and Agriculture Organization.[26] Mitchell, A. L., Rosenqvist, A. & Mora, B. (2017). Current remote sensing approaches to monitoring forest degradation in support of countries measurement, reporting and verification (MRV) systems for REDD+. Carbon Balance and Management, 12, 9.[27]

[24] It should be noted that studies by market practitioners have found that NDVI (Landsat and Sentinel-2) exhibit large within-year variation associated with seasonal increases in vegetation greenness or density. In addition, SI based on NDVI can reach their maxima early into reforestation, because all pixels will contain relatively dense vegetation once the forest canopy closes, even though tree size and carbon content will continue to increase for decades.

[25] https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

[26] https://www.fs.usda.gov/research/treesearch/56461;https://www.fs.fed.us/rm/pubs_journals/2020/rmrs_2020_espej o_a001.pdf 18

[27] https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-017-0078-9

	Where a project proponent
Purpose of data:	Selection of control plots and derivation of performance benchmark for the area-based approach
Calculation method:	N/A
Comments:	Note that SI may be derived using different remote sensing metrics for the selection of control plots and for monitoring the performance benchmark. It is expected that the same remote sensing technology may not be available for both the historical analysis (selection of control plots) and monitoring ex post. The same remote sensing metric must be used for monitoring SI ex post in both control plots and project sample plots. Where more accurate remote sensing metrics become available over time, the remote sensing metric used for monitoring SI ex post may be changed when: 1) The new metric offers equivalent or better accuracy (in terms of correlation with terrestrial carbon stocks); 2) It is possible to harmonize the new metric with the previous metric, applying procedures from peer-reviewed literature[28] to ensure data continuity and remove sources of misalignment (e.g., geometric, radiometric and/or spectral artifacts) introduced by the new metric; 3) The procedure to harmonize the new metric incorporates temporally coincident observations of both (previous and new) remote sensing metrics from the project and control plots from within an overlap interval of not less than two years, or as prescribed by the procedure. All project and control sites shall be made publicly available (precise geospatial locations).

[28] e.g., https://www.usgs.gov/landsat-missions/harmonizing-landsat-archive

Document History

Version	Date	Changes
V1.0	24th April 2024	Initial version released.