PLAN VIVO

PV Climate Methodology

PM002

Methodology for Quantifying Carbon Benefits from Small-scale Agroforestry

Version 1.0

29 October 2025

Developed by:

Acorn

Planting a better future with smallholder farmers | Acorn Rabobank

Approved by:

AENOR

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1 Summary

This *Methodology* describes the procedures for measuring change in *carbon stock(s)* and calculating the amount of carbon removals from the atmosphere by adopting *agroforestry* practices. This version includes some key developments amongst others:

- advancing applicability conditions;
- including complementary *Modules* that describe in detail the model calibration strategy;
- integrating procedures for compensating *harvesting* in the carbon calculations;
- elaborating further on the methods for estimating *Aboveground Biomass* and pre-project trees analysis using data-driven approaches.

This *Methodology* is applicable to all *Projects* that implement *agroforestry* practices by *Smallholders* on small-scale farms that are not on *wetlands*. To estimate the change in *Aboveground* and *Belowground Biomass* attributable to *Project Interventions* between two points in time, the *Methodology* incorporates direct measurement of trees in *sample plots* and interpretation of satellite imagery using model(s) calibrated on *sample plot* data from the *ecoregion* within which the *Project* is located.

This *Methodology* provides details on carbon counting procedures that can be used in small-scale *agroforestry Projects* that generate *Plan Vivo Certificates (PVCs). Carbon benefits* are calculated following this approved *Methodology* and *reported and verified Plan Vivo Certificates (rPVCs and vPVCs)* representing those *carbon benefits* can be issued with *Projects* adhering to PV Climate Project Requirements. This *Methodology* is designed following the Plan Vivo PV Climate Methodology requirements v1.2.

2 Sources

Where applicable, this *Methodology* applies the following program-related *Modules*/ *Tools*:

PU003 Estimation of baseline and project GHG emissions from emission sources in Plan Vivo projects v1.0

PU004 Estimation of GHG emissions from leakage in Plan Vivo projects v1.0

PU006 Module for Model Development, Calibration, Validation and Application of Remote Sensing-based Models of Aboveground Biomass in Smallholder Agroforestry v1.0

PU007 Module for Performing Adaptive Pre-project Woody Biomass Baseline for Small-scale Agroforestry v1.0

PU008 Module for Estimating Uncertainty of Carbon Benefits from Small-scale Agroforestry v1.0

PU009 Module for Estimation of Carbon Benefits from Small-scale Agroforestry with Partial Felling and Harvesting of Trees v1.0

PT005 Tool for Assessment of Historic Deforestation on Small-scale Agroforestry v1.0

PT006 Tool for Ground Truth Sampling v1.0

This *Methodology* applies procedures from the following existing *Methodology* and *Tools.* References can be found in Section 12;

AR-AMS0007 Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands v2.0

AR-TOOL02 Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities v1.0

AR-TOOL04 Tool for testing significance of GHG emissions in A/R CDM project activities, Version 1.0

AR-TOOL14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities v4.2

PM001 Agriculture and Forestry Carbon Benefit Assessment Methodology v1.0

This *Methodology* references the following IPCC Guidance:

IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4 Agriculture, Forestry and Other Land Use.

3 Definitions

All terms in this document follow the PV Climate Glossary, with the addition of the following definitions:

Aboveground Biomass (AGB)

The total mass of living matter above the ground expressed as dry weight (e.g. trees and *shrubs*).

Agroforestry

A holistic farm management system made up of a range of strategies, where woody plants are intentionally integrated with crops and/or livestock to generate *carbon benefits*, *livelihood benefits,* and *ecosystem benefits* on the same parcel of land.

Agroforestry Design

A description of an *agroforestry* system that will be established and managed under a *Project*, including crop and/or pastoral farming practices, selected tree species, the arrangement of trees, crops and/or livestock, the interaction of components in the system, and sustainable land use and management practices. The *Agroforestry Design* for a *Project* will be prepared by Local Agronomists together with the *Project Coordinator* and *Stakeholders* and is part of the *Project Design Document*.

Animal husbandry

A branch of agricultural activities that includes the production and care of domesticated animals.

Belowground Biomass (BGB)

The total mass of living matter below the ground expressed as dry weight.

(Woody) Biomass

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

Carbon recovery time

A time period in which *carbon stock* recovers to levels directly prior to the *partial felling* or *harvesting* activity.

Carbon reversal

An escape or release of stored carbon or otherwise sequestered CO_2 back into the atmosphere, resulting from a *reversal event* during the *Crediting Period* and/or the *Durability Period*.

Carbon sequestration

A process by which carbon dioxide (CO_2) is captured and stored in *carbon pool* (s), therefore reducing the amount of CO_2 in the atmosphere.

Carbon stock

The quantity of carbon stored in a given *carbon pool*.

Deforestation

The act of clearing trees (human-induced) resulting in natural forest land being converted to non-forest land.

Deforestation assessment

An evaluation to determine whether *deforestation* activities have taken place on a *Project Area* within 10 years before *Project Area* onboarding for the purpose of onboarding.

Durability Period

A 25-year period, commencing the year each *r/vPVC* is generated, during which the CO_2e represented by a *r/vPVC* is expected to remain removed from the atmosphere and stored in a *carbon pool*.

Ecoregion

A large area of land and/or water, ecologically and geographically characterized by distinct ecosystems, flora, and fauna, as further defined in the 'terrestrial scheme' by WWF, see also: *Terrestrial Ecoregions of the World | Publications | WWF (worldwildlife.org)*.

Enteric fermentation

The fermentation that takes place in the digestive system of animals, especially ruminant animals, that results in methane emissions.

Ground truth data

Biomass measurements collected on-site by manually counting and measuring trees in a specific *sample plot* to know the "true" *biomass* in the field. This data is used for *validation* purposes to test and determine model accuracy.

Ground truth measurement

The realization of an inventory through manual measurement and counting of trees in a specific *sample plot*.

Harvesting

Activity of removing *biomass* as part of the *Project Intervention* after the establishment of the *agroforestry* system, resulting in a *carbon recovery time* to pre-*harvesting* levels of more than 5 years during the *Crediting Period*, or when *carbon stock* reductions are above 20% over this 5-year period.

Heavy machinery

Machinery, such as large tractors, that generally do not form part of regenerative agricultural practices due to high *soil disturbance*, emissions and use of non-renewable energy excluding necessary hand-operated machinery, such as chainsaws (that may require non-renewable energy).

Irrigation

The artificial supply of water to land or crops to help growth.

Manure decomposition

A microbe-mediated process that leads to the degradation or mineralization of organic compounds in manure, which results in methane and nitrous oxide emissions.

Measurement Period

Difference between two points in time that defines the period for estimation of a *r/vPVC*.

Monitoring

Activities of collecting and recording data in accordance with any relevant standards or conditions provided for in the PV Climate Project Requirements v5.2 and this *Methodology* to determine the impact underlying the carbon removals resulting from a *Project*.

Naturalized species

Plant or animal species, also known as exotic species, that have been introduced into the ecosystem in the 20th century or earlier as a result of human interference and can reproduce harmoniously in the new environment.

Partial felling

Activity of removing *biomass* (i.e. thinning) as part of the *Project Intervention* after the establishment of the *agroforestry* system, resulting in a *carbon stock* reduction below 20% over this 5-year period, starting when a reduction of *carbon stock* occurs, and with *carbon stock* recovered within the 5-year period.

Pre-project tree biomass

Pre-project tree biomass is the tree *biomass* in a *Project Area prior to the start of the Project Intervention.*

Project Area Level

A term used to describe a type of *monitoring*, data collection or reporting that takes place at the level of the individual *Project Participant's* land.

Project level

A term used to describe a type of *monitoring*, data collection or reporting that is based on input from the *Project Coordinator* or a sample of *Project Participants* from a *Project*, that views the *Project* as a whole without looking at each specific *Project Area*.

Reversal event

An avoidable or unavoidable event or circumstance occurring after the transfer of a *vPVC* that results, or is reasonably likely to result, in a *carbon reversal* during the *Project Period*. An avoidable event refers to activities that could have otherwise been avoided through appropriate implementation of the *Project*, such as improper management. An unavoidable event refers to activities that the *Project Coordinator* cannot have been reasonably expected to manage, for example, extreme weather events or social unrest.

Sample plot

An area of a maximum of 1 ha within a *Project Area*, where *ground truth measurements* take place.

Shrubs

Species which are woody non-climbing plants without a clearly defined main stem, branching off below stem height of 1.30 meters, with a maximum species height smaller than 5 meters.

Silvopastoral projects

Projects that combine silvicultural practices in combination with *animal husbandry*, i.e. the planting of trees, bushes and forage for the benefits of raised farm animals. *Silvopastoral projects* are those where the *Agroforestry Design* is purposefully designed for farming on *Project Areas* where the main economic dedication is *animal husbandry* with ruminants (cattle, buffalo, sheep and goat).

Smallholder

A *Project Participant* who carries out agricultural land management activities on a small area of land (0.1 – 10 ha) or a *Project Participant* with larger areas who is not structurally dependent on hired labour all year round.

Soil disturbance

The act of disturbing and affecting soil structure and exposure to wind and water as a result of certain farming practices (e.g. ploughing, ripping, scarification, digging of pits, stump removal,

compaction by vehicles) which often results in e.g. reduced vegetative growth capacity, soil aeration and higher erosion risks.

Soil Organic Carbon (SOC)

A measure of carbon contained in soil organic matter. It is a *carbon pool* of carbon stored in soil.

Uncertainty

The calculated percentage of temporal change of the *Aboveground Biomass* in a *Project Area* that determines the *uncertainty* adjustment factor following the procedures outlined in this *Methodology*.

Wetlands

Land that is covered or saturated by water for all or part of the year (e.g. marshes, swamps, peatland).

4 Applicability Conditions

4.1 Project Interventions

This *Methodology* is applicable to all *Project Interventions* that result in the removal of greenhouse gas emissions from the atmosphere by *agroforestry* practices. It is applicable in any geographic location that fulfills the following applicability conditions:

1. *Project Interventions* must meet the *agroforestry* definition (see Section 3), and any trees planted are to be *native* or *naturalized species*.
2. *Project Areas* must meet the *deforestation assessment* within 10 years before onboarding (see **PT005**) and provide evidence of no clearance of woody vegetation, or significant *soil disturbance* within the 10 years prior to *Project Area* onboarding, unless any such occurrences were the result of natural processes or *loss event*.
3. *Project Interventions* must not take place on *wetlands; natural ecosystems* must not be converted to generate *carbon benefits*.
4. Additional trees would not be planted without the *Project Interventions*.
5. *Project Interventions* must not increase the use of synthetic (nitrogen-containing) fertilisers that will significantly increase nitrogen fertiliser emissions relative to the *baseline scenario*.
6. *Project Interventions* must not involve slash-and-burn activity.
7. *Soil disturbance* attributable to the *Project Interventions* must not occur on more than 10% of the *Project Area* that falls within either of the following categories of land:

- Land containing organic soils (see Section 13.1)[1];
- Land which, in the *baseline scenario*, is subjected to the land-use and practices and inputs described in Section 13.2.

8. *Project Interventions* must exclude flooding, and must not include *irrigation* practices that will significantly increase methanogenesis relative to the *baseline scenario.*
9. Any litter generated as a result of *Project Interventions* must remain on the *Project Area*.

The applicability conditions ensure that *Project Interventions* applying this *Methodology* fall within the eligible category of *Projects,* indicating that emissions through litter, deadwood and soil can be conservatively assumed to be zero in the *baseline scenario* and meeting environmental safeguards as per the PV Climate.

4.2 Certificate Type

The approaches in this *Methodology* can be used to produce *reported and verified Plan Vivo Certificates* (*rPVCs* and *vPVCs*) from *Project Interventions* that generate net GHG removals. *rPVCs* can be claimed when *carbon benefits* are reported in an *Annual Report* to Plan Vivo. *vPVCs* can be claimed when *carbon benefits* have been verified. Further details and procedures for conversion between certificate types are described in the Plan Vivo Procedures Manual.

5 Carbon Pools and Emission Sources

The following *carbon pools* and emission sources are considered when assessing the *carbon baseline* and *Project* removals. All *carbon pools* and emissions sources that could result in higher net emissions in the *Crediting Period* due to *Project Intervention* compared to the *carbon baseline* must be included in the assessment, unless it can be demonstrated that all excluded *carbon pools* and emissions sources combined could reduce the total *carbon benefit* for the *Project* by less than 5%.

To support the exclusion of specific *carbon pools* and emission sources, simplified methods (e.g. default values) or the procedures outlined in **AR-TOOL04** can be applied to demonstrate their insignificance. Any assumptions made in this process must be clearly justified in the *Project* documentation and, where possible, supported by relevant evidence.

[1] If land contains high organic soils, *Projects* are expected to contract agreements on limited *soil disturbance* and clearly stated how *soil disturbance* is taken into account at the *Agroforestry Design*.

Table 1. Carbon pools

Carbon pool	Included/excluded	Justification
Aboveground woody biomass	Included	A *carbon pool* expected to be significantly impacted by *Project Interventions*
Belowground woody biomass	Included	A *carbon pool* expected to be significantly impacted by *Project Interventions*
Non-*woody biomass*	Include if significant	A *carbon pool* that must be included where the *Project Intervention* leads to a significant reduction in total expected *carbon benefits*
Litter	Excluded	*Project Interventions*, conservatively excluded due to Applicability condition 9
Deadwood	Include if significant	A *carbon pool* that must be included where the *Project Intervention* leads to a significant reduction in total expected *carbon benefits*
SOC	Include if significant	A *carbon pool* that must be included where the *Project Intervention* leads to a significant reduction in total expected *carbon benefits*
Harvested wood products	Excluded	Conservative to be excluded

Table 2. Emissions sources

Emission sources	Included/excluded	Justification
Nitrogen fertilisers (N_2O)	Include if significant	An emission source that must be included where the *Project Intervention* significantly leads to a reduction in total expected *carbon benefits.* Emissions from nitrogen fertilisers are expected to be unaffected or increased up to 5% by *Project Intervention* limited due applicability condition 5
Nitrogen fixing species (N_2O)	Include if significant	An emission source that must be included where the *Project Intervention* significantly leads to a reduction in total expected c*arbon benefits.* Emissions from the nitrogen fixing species in a

		small-scale *agroforestry* system is considered limited (Kou-Giesbrecht & Menge, 2021)
(*Woody* and non-*woody*) *Biomass* burning (CO_2)	Excluded	Slash and burn agriculture with the intention to prepare sites is not promoted under this *Methodology*. Conservative to exclude
Fossil fuel use (CO_2)	Include if significant	An emission source that must be included where the *Project Intervention* significantly leads to a reduction in total expected *carbon benefits.* The use of *heavy machinery* is considered unlikely in small-scale *agroforestry* and not promoted for site preparation or management within *Projects*
Enteric fermentation (CH_4)	Include for *silvopastoral projects*	Emissions from non-*silvopastoral projects*, where presence of ruminant animals is considered limited at small-scale *agroforestry*, are considered non-significant and are excluded. For *silvopastoral projects*, this emissions source should be included
Manure decomposition (CH_4, N_2O)	Include for *silvopastoral projects*	Emissions from non-*silvopastoral projects*, where presence of ruminant animals is considered limited at small-scale *agroforestry, are* considered non-significant and are excluded. For *silvopastoral projects*, this emissions source should be included
Soil methanogenesis (CH_4)	Excluded	An emission source that must be included where the *Project Intervention* significantly leads to a reduction in total expected c*arbon benefits.* Emissions from nitrogen fertilisers are expected to be unaffected or reduced by *Project Intervention* limited due applicability condition 8

6 Baseline Scenario and Additionality

Project Coordinator must determine the most likely land use and land management practices in a *Project Area*, over a period of at least the next 10 years, in the absence of the *Project Interventions* using **AR-AMS0007** *Simplified baseline and monitoring methodology for small scale CDM afforestation and reforestation project activities implemented on lands other than wetlands* v2.0 or **AR-TOOL02** *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities v1.0* and report this in the *baseline scenario* section of the *Project Design Document*. The *baseline scenario* is determined using **AR-AMS0007** presuming continuation of the pre-project land use or by identifying all plausible alternative scenarios using **AR-TOOL02**.

Additionality of the *Project Interventions* must be determined following the barrier analysis instructions of the *Tool* applied for the *baseline scenario*. The data required for this analysis comes mostly from *Stakeholder* consultations with the *Project Participants* and *Project Coordinator*, and where possible will be backed up by historical data and/or scientific literature.

The data gathered on *additionality* is (re-)assessed against the requirements in PV Climate and reported on in the *additionality* section of the *Project Design Document*.

Project Coordinator must re-assess both the *baseline scenario* and *additionality* of an *Project*, using annex of **AR-AMS0007** or step 1 and step 2 described in **AR-TOOL02** *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities v1.0,* at least every 10 years throughout the *Crediting Period*.

6.1 Ecoregion(s)

Project Area(s) are stratified and defined by *ecoregions* (Olson, D. M, et al, 2001). Per *ecoregion*, *sample plots* are collected and applied to locally validate and calibrate the *biomass* model(s). For each *Project*, a calibration strategy based on stratified systematic approach is followed to ensure a representative selection of *sample plots*, which cover the full *biomass* variation (**PT006**). By default, a minimum of 30 *sample plots* must be surveyed in each *ecoregion* at the start of the *Project Interventions*. In the years thereafter, a minimum of 30 additional *sample plots* must be surveyed in each *ecoregion* at least every 5 years and applied to enhance model performance. Up to 300 *Project Areas* within a *Project Region* can belong to a non-calibrated *ecoregion* if the non-calibrated *ecoregion* is adjacent to a calibrated *ecoregion*. The *Project Areas* have to have the same *Agroforestry Design*, and be within the same calibration range as *Project Areas* within the calibrated *ecoregion*. In this case models from the adjacent calibrated *ecoregion* should be applied.

6.2 Root:shoot ratio

Root:shoot ratio is defined as the ratio of *Belowground Biomass* to *Aboveground Biomass*. If no transparent, scientific and verifiable information is available to justify a specific root:shoot ratio, an appropriate *ecoregion* level root:shoot ratio should be determined following Table 4.4[2] from the IPCC (2019) report to calculate *Belowground Biomass* value(s). Ecological zones are assigned to the *ecoregions* to assign a corresponding root:shoot ratio following FAO (2012). If a *Project* includes multiple *ecoregions*, a weighted average value will be assigned to the *Project* for *biomass* below 125 t/ha. The category exceeding 125 t/ha falls outside of the scope of this *Methodology*, as such *biomass* values are deemed too high for *agroforestry* practices. If an ecological zone cannot be mapped to an *ecoregion*, or if Table 4.4 from IPCC (2019) cannot be used for any reason, a default value of 0.32 (Kim, Kirschbaum & Beedy, 2016) should be applied. Please refer to the IPCC (2019) Table 4.4 and Equation 1 for the equation in which the root:shoot ratio is applied. The root:shoot ratio is applied to calculate the *Belowground Biomass* as shown in Equation 1.

$$BGB_{\Delta,p} = AGB_{\Delta,p} \cdot R$$

Equation 1

Where:

$BGB_{\Delta,p}$	= Change in *Belowground Biomass* during *Measurement Period p* (tonne)
$AGB_{\Delta,p}$	= Change in *Aboveground Biomass* during *Measurement Period p* (tonne; see **PU006**)
R	= Root:shoot ratio

7 Carbon Baseline

7.1 Pre-project tree Adjustment

[2]IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch04_Forest%20Land.pdf

r/vPVCs may only be issued on *biomass* increase that results from the *Project Interventions*, therefore *biomass* considered existing before the start of the *Project Interventions* should be adjusted for.

The amount of *biomass* present within the *Project Area* prior to the start of the *Project Period*, its projected *biomass* contribution, as well as the associated *uncertainty* ($AdjU_{EETBs,t}$), are determined following the *Methodology* with an adjustment factor ($AdjB_{s,t}$) value explained in *Module* **PU007**.

7.2 Baseline Scenario Emissions from Emission Sources

Emissions from emission sources under the *baseline scenario* are estimated using the equations in **PU003**. All significant emission sources are combined under one parameter and scaled to the *Project Area* following Equation 2.

$$ES_{\Delta,p,b} = \left(\frac{ES_{p,b}}{PA_p}\right) * area$$

Equation 2

Where:

$ES_{\Delta,p,b}$ = *Baseline scenario* GHG emissions from a specific *Project Area* within *Measurement Period p* (t CO_2e)

$ES_{p,b}$ = *Baseline scenario* GHG emissions from a *Project* throughout *Measurement Period p* for all significant emission sources (t CO_2e; see **PU003**)

PA_p = Extent of all *Project Areas* of a *Project* at *Measurement Period p* (ha)

$area$ = Extent of *Project Area* (ha)

If the *baseline scenario* is a continuation of pre-project land use, emissions from emission sources can be assumed to remain constant at the pre-project rate throughout the *Crediting Period*.

8 Project Emission and Removals

8.1 Expected project emissions and removals

Expected net GHG emissions/removals due to *Project Intervention* compared to the *carbon baseline* in the *Project Period* can be estimated by applying the procedures in *Module* **PU001** for *carbon pools* and *Module* **PU003** for emission sources.

8.2 Actual project emissions and removals

Net GHG emissions and removals due to *Project Intervention* compared to the *carbon baseline* must be estimated at least every 5 years throughout the *Project Period*, by applying the procedures in *Module* **PU003** with all significant emission sources combined under one parameter and scaled to the *Project Area* following Equation 3, and *Module* **PU006** respectively.

$$ES_{\Delta,p} = \left(\frac{ES_p}{PA_p}\right) * area$$

Equation 3

Where:

$ES_{\Delta,p}$	= *Project scenario* GHG emissions from a specific *Project Area* within *Measurement Period p* (t CO_2e)
ES_p	= *Project scenario* GHG emissions from a *Project* throughout *Measurement Period p* for all significant emission sources (t CO_2e; see **PU003**)
PA_p	= Extent of all *Project Areas* of a *Project* at *Measurement Period p* (ha)
$area$	= Extent of *Project Area* (ha)

9 Leakage

If there is potential for significant GHG emissions from activity shifting *leakage*, activity shifting *leakage* emissions must either be estimated, or a conservative *leakage* discount factor must be applied. Procedures in **AR-TOOL04 v1.0** are used to demonstrate the significance of potential *leakage* emissions. If significant, *leakage* is accounted for by following the *Methodology* explained in *Module* **PU004**. The parameters in **PU004** are adapted as follows to correspond to the parameters used in this *Methodology*.

i. The calculation of potential *leakage* discount factor $LD_{CP,a}$ and $LD_{ES,a}$ in **PU004** is summed and replaced by $LD_{CP,ES}$ below.
ii. The calculation of potential *leakage* emissions $LE_{CP,a,y}$ and $LE_{ES,a,y}$ in **PU004** is replaced by $LE_{CP,ES,t}$ and $LE_{CP,ES,t-p}$ below.

If a *leakage* discount factor approach is adopted, the accounted *leakage* emissions are added to Equation 6.1 and Equation 6.2 through the *leakage* discount factor $LD_{CP,ES}$; if a *leakage* estimation approach is adopted, the terms "· (1 – $LD_{CP,ES}$)" in Equation 6.1 and Equation 6.2 should be replaced with "– $LE_{CP,ES,\Delta,p}$" as appropriate:

$$LE_{CP,ES,\Delta,p} = LE_{CP,ES,t} - LE_{CP,ES,t-p}$$

Equation 4

Where:

$LE_{CP,ES,\Delta,p}$ = GHG emissions due to *carbon pool* and emission sources *leakage* in a *Project* within *Measurement Period p* (t CO_2e)

$LE_{CP,ES,t}$ = GHG emissions due to *carbon pool* and emission sources *leakage* from a *Project Area* up to the most recent measurement point in time t (t CO_2e; see **PU004**)

$LE_{CP,ES,t-p}$ = GHG emissions due to *carbon pool* and emission sources *leakage* from a *Project Area* up to the most recent measurement point in time t minus *Measurement Period p* (t CO_2e; see **PU004**)

9.1 Potential leakage emissions

Potential *leakage* emissions are estimated by applying the procedures in an approved *Module* or *Tool*. *Modules* and *Tools* can include one or more of the following approaches:

i. Modelling based on expected activity displacement and/or market *leakage* (see **PU004**)
ii. *Leakage* discount factor based on characteristics of the *Project Area* and *Project Intervention* (see **PU004**)

9.2 Actual leakage emissions

Leakage that occurs during a *Project Period* is estimated by applying the procedures in an approved *Module* or *Tool*. *Modules* and *Tools* can include one or more of the following approaches:

i. Measurement of activity shifting and/or market *leakage* (see **PU004**)
ii. *Leakage* discount factor based on characteristics of the *Project Area* and *Project Intervention* (see **PU004**)

10 Calculation of Carbon Benefits

10.1 Uncertainty Adjustment

The *uncertainty* value for *Projects* is calculated following the *Methodology* explained in *Module* **PU008**. Only *Project Areas* that require 50% or less *uncertainty* adjustment ($AdjU$) are considered eligible for *r/vPVC* calculation. For *Project Areas,* that require *uncertainty* adjustment above 50%, the *Measurement Period* is extended by number (n) of years until the 50% (or less) *uncertainty* adjustment on *Project Area Level* is reached.

10.2 Partial felling & Harvesting

Projects are allowed to have *partial felling* and/or *harvesting* activities within the *Project Interventions*. The calculation of *Aboveground Biomass* due to *harvesting* follows the *Methodology* explained in *Module* **PU009**.

Such *Projects* can generate *r/vPVCs* up to the amount of $AGB_{\Delta,cap}$ (see *Module* **PU009**). Equation 5 calculates the amount of potential *AGB* available for *r/vPVC* generation in *Measurement period p*. If $AGBr$ is positive, Equation 1, Equation 6.1, and Equation 6.2 can be applied, where $AGB_{\Delta,p}$ is lower than or takes a maximum value of $AGBr$. If $AGBr$ is negative, $AGB_{\Delta,p}$takes a value of zero.

$$AGB_r = (AGB_{\Delta,cap} * area) - \sum_{p=1}^{n-1} \max(0, AGB_{\Delta,p})$$

Equation 5

Where:

AGB_r = Potential *AGB* with *vPVC* potential per *Project Area* (tonne)

$AGB_{\Delta,cap}$ = Maximum long-term average *Aboveground Biomass* increase from the *Project Intervention* in the *Project Area(s)* in the *Project Period* for *r/vPVC* issuance (tonne/ha) from *Module* **PU009**

$AGB_{\Delta,p}$ = Change in *Aboveground Biomass* during *Measurement Period p* (tonne; see **PU006**)

$area$ = Extent of *Project Area* (ha)

n = Number of *Measurement Periods* since *Project Area* onboarding

10.3 Plan Vivo Certificates

10.3.1 Future PVCs

Projects are not allowed to issue *future Plan Vivo Certificates (fPVCs)* following this *Methodology*.

10.3.2 Reported and Verified PVCs

Projects are allowed to issue *reported* and/or *verified Plan Vivo Certificates (r/vPVCs)* following this *Methodology*. All carbon models are developed from a combination of *sample plot* measurements and satellite imagery and are specific to an *ecoregion*. Equation 6.1 and Equation 6.2 describe how to calculate the number of *r/vPVCs* that can be issued from the change in various *carbon pools* and emission sources.

Calculation of rPVC issuance

$$rPVC = ((AGB_{\Delta,p} + BGB_{\Delta,p}) \cdot CF) \cdot C \cdot (1 - AdjB_{s,t}) \cdot (1 - AdjU) \cdot (1 - LD_{CP,ES}) \cdot (1 - AR) \cdot (1 - fRB) - (ES_{\Delta,p} - ES_{\Delta,p,b})$$

Equation 6.1

Where:

$rPVC$ = *Reported Plan Vivo Certificate* (t CO_2e)

$AGB_{\Delta,p}$ = Change in *Aboveground Biomass* during *Measurement Period* (tonne; see **PU006**)

$BGB_{\Delta,p}$ = Change in *Belowground Biomass* during *Measurement Period* (tonne)

CF = Carbon fraction of *biomass* = 0.47

C = Conversion from carbon to carbon dioxide = $\frac{44}{12}$

$AdjB_{s,t}$ = Adjustment factor for *pre-project tree biomass* (%; see **PU007**)

$AdjU$ = Adjustment factor for *uncertainty* (%; see **PU008**)

$LD_{CP,ES}$ = *Leakage* discount factor for *carbon pool* and emission sources *leakage* (%; see **PU004**)

AR = *Achievement reserve*, the proportion of expected *carbon benefits* withheld to mitigate the risk of underperformance (10%)

fRB = Proportion of *rPVCs* contributed to the *future Risk Buffer* (20%)

$ES_{\Delta,p,b}$ = *Baseline scenario* GHG emissions from a specific *Project Area* within *Measurement Period* p (t CO_2e)

$ES_{\Delta,p}$ = GHG emissions due to *Project Intervention* from a specific *Project Area* within *Measurement Period p* (t CO_2e)

Calculation of vPVC issuance

$$vPVC = ((AGB_{\Delta,p} + BGB_{\Delta,p}) \cdot CF) \cdot C \cdot (1 - AdjB_{s,t}) \cdot (1 - AdjU) \cdot (1 - LD_{CP,ES}) \cdot (1 - RB) - (ES_{\Delta,p} - ES_{\Delta,p,b})$$

Equation 6.2

Where:

$vPVC$ = *Verified Plan Vivo Certificate* (t CO_2e)

$AGB_{\Delta,p}$ = Change in *Aboveground Biomass* during *Measurement Period* (tonne; see **PU006**)

$BGB_{\Delta,p}$ = Change in *Belowground Biomass* during *Measurement Period* (tonne)

CF = Carbon fraction of *biomass* = 0.47

C = Conversion from carbon to carbon dioxide = $\frac{44}{12}$

$AdjB_{s,t}$ = Adjustment factor for *pre-project tree biomass* (%; see **PU007**)

$AdjU$ = Adjustment factor for *uncertainty* (%; see **PU008**)

$LD_{CP,ES}$ = *Leakage* discount factor for *carbon pool* and emission sources *leakage* (%; see **PU004**)

RB = Proportion of *vPVCs* contributed to the *Risk Buffer* (20%)

$ES_{\Delta,p,b}$ = *Baseline scenario* GHG emissions from a specific *Project Area* within *Measurement Period p* (t CO_2e)

$ES_{\Delta,p}$ = GHG emissions due to *Project Intervention* from a specific *Project Area* within *Measurement Period p* (t CO_2e)

r/vPVCs can be calculated up to 6 months, depending on the measuring date, prior to *Project Area* onboarding. After *r/vPVC* issuance, negative *biomass* values need to be compensated by additional *biomass* growth before new *r/vPVC* issuance or by the *risk buffer* after a *reversal event*.

10.3.3 PVC Conversion

If a *Project* has been issued with *rPVCs* these must be converted to *vPVCs* before any additional *vPVCs* are issued.

11 Parameters

Data/Parameter	$AdjB_{s,t}$
Units	%
Description	Adjustment factor for *pre-project tree biomass*
Equations	Equation 6.1 and Equation 6.2
Source	**PU007**, Table 1
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	The adjustment is required in order to ensure fair compensation.
Purpose of Data	Determine to adjust for *biomass* growth of trees planted before the *Project Interventions*
Comments	N/A

Data/Parameter	$AdjU$
Units	%
Description	Adjustment factor for *uncertainty* on *Project Area Level*
Equations	Equation 6.1 and Equation 6.2
Source	**PU008**
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	The adjustment is required in order to ensure fair compensation.
Purpose of Data	Determine to adjust for *uncertainty* of calculations
Comments	N/A

Data/Parameter	$AGB_{\Delta,cap}$
Units	Tonne
Description	Maximum long-term average *Aboveground Biomass* increase from the *Project Intervention* in the *Project Area(s)* in the *Project Period* for *r/vPVC* issuance
Equations	Equation 5
Source	**PU009**
Value	N/A

Justification of choice of data or description of measurement methods and procedures applied	$AGB_{\Delta,cap}$ is determined based on the long-term average for a 50-year period. It is used to account for *harvesting* over the long-term implementation of the *agroforestry* system.
Purpose of Data	Estimation of the maximum long-term average *Aboveground Biomass* increase from the *Project Intervention* for *harvesting* activities
Comments	N/A

Data/Parameter	$AGB_{\Delta,p}$
Units	Tonne
Description	Change in *Aboveground Biomass* during *Measurement Period*
Equations	Equation 1, Equation 5, Equation 6.1, and Equation 6.2
Source	Satellite imagery; *Aboveground Biomass* is estimated using a machine learning model (Shen et al. (2022)) and is explained in **PU006**
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Satellite imagery is used as input for *biomass* model to estimate *biomass* at two moments in time.
Purpose of Data	Estimation of *Aboveground Biomass* contributions to total *Project* removals
Comments	N/A

Data/Parameter	AR
Units	No unit
Description	Proportion of expected *carbon benefits* withheld to mitigate the risk of underperformance
Equations	Equation 6.1
Source	PV Climate Project Requirement 3.10.2
Value	0.1
Justification of choice of data or description of measurement methods and procedures applied	See PV Climate Project Requirement v5.2
Purpose of Data	Calculation of *rPVCs*

Comments	N/A

Data/Parameter	$area$
Units	ha
Description	Extent of *Project Area*
Equations	Equation 2, Equation 3, and Equation 5
Source	*Ground truth data* collection
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See **PU009**
Purpose of Data	Calculation of emission sources relative to the size of the *Project Area*; Calculation of AGB_r under *harvesting* activities
Comments	N/A

Data/Parameter	C
Units	No unit
Description	Conversion from carbon to carbon dioxide
Equations	Equation 6.1 and Equation 6.2
Source	IPCC, 2006
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	Conversion from carbon to carbon dioxide = $\frac{44}{12}$
Purpose of Data	Widely used conversion
Comments	N/A

Data/Parameter	CF
Units	No unit
Description	Carbon fraction of *biomass*
Equations	Equation 6.1 and Equation 6.2
Source	IPCC, 2006
Value	Number

Justification of choice of data or description of measurement methods and procedures applied	Carbon fraction of *biomass* = 0.47
Purpose of Data	Widely used conversion
Comments	N/A

Data/Parameter	ES_p
Units	t CO_2e
Description	*Project scenario* GHG emissions from a *Project* throughout *Measurement Period p* for all significant emission sources (t CO_2e; see **PU003**)
Equations	Equation 3
Source	ES is a combination of all eligible emission sources described in **PU003**.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Estimation of the emission sources contributions to the reduction of the total *Project* removals
Purpose of Data	Input value for determining the accounted emission sources from the *Project*, if significant, from a *Project Area*
Comments	N/A

Data/Parameter	$ES_{p,b}$
Units	t CO_2e
Description	*Baseline Scenario* GHG emissions from a *Project* throughout *Measurement Period* p for all significant emission sources (t CO_2e; see **PU003**)
Equations	Equation 2
Source	ES is a combination of all eligible emission sources described in **PU003**.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Estimation of the emission sources contributions to the reduction of the total *Project* removals for *Baseline Scenario*
Purpose of Data	Input value for determining the accounted emission sources, if significant, from *Baseline Scenario* in a *Project Area*
Comments	N/A

Data/Parameter	fRB
Units	No unit
Description	Proportion of *rPVCs* contributed to the pooled *future Risk Buffer*
Equations	Equation 6.1
Source	PV Climate Project Requirement 3.11.4
Value	0.2
Justification of choice of data or description of measurement methods and procedures applied	See PV Climate Project Requirement v5.2
Purpose of Data	Calculation of *rPVCs*
Comments	N/A

Data/Parameter	$LD_{CP,ES}$
Units	%
Description	*Leakage* discount factor for *carbon pools* and emission sources *leakage* in a *Project Area*
Equations	Equation 4
Source	$LD_{CP,ES}$ is the sum of the two parameters $LD_{CP,a}$ and $LD_{ES,a}$ described in **PU004**.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module **PU004**.
Purpose of Data	Input value for determining the related *leakage* emissions, if significant, from *carbon pools* and emission sources
Comments	N/A

Data/Parameter	$LE_{CP,ES,p}$; $LE_{CP,ES,t-p}$
Units	t CO_2e
Description	GHG emissions due to *carbon pool* and emission sources *leakage* from a *Project Area* up to the most recent measurement point in time; GHG emissions due to *carbon pool* and emission sources *leakage* from a *Project Area* up to the most

	recent measurement point in time t minus *Measurement Period p*
Equations	Equation 4
Source	$LE_{CP,ES}$ is the sum of the two parameters $LE_{CP,a,y}$ and $LE_{ES,a,y}$ described in **PU004**.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module **PU004**.
Purpose of Data	Input value for determining the related *leakage* emissions, if significant, from *carbon pools* and emission sources
Comments	N/A

Data/Parameter	PA_p
Units	ha
Description	Extent of all *Project Areas* of a *Project* at *Measurement Period p*
Equations	Equation 2 and Equation 3
Source	*Ground truth data* collection
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Change in emission sources in a *Project* must be calculated on a *Project Level* and applied on a *Project Area* relative to the size of the *Project Area*.
Purpose of Data	Calculation for emission sources relative to the size of the *Project Area*
Comments	N/A

Data/Parameter	R
Units	No unit
Description	Root:shoot ratio for the calculation of *Belowground Biomass*
Equations	Equation 1
Source	IPCC, 2019 Chapter 4 Forest land Table 4.4
Value	Between 0 and 1

Justification of choice of data or description of measurement methods and procedures applied	A method in line with international standards.
Purpose of Data	Calculation for *Belowground Biomass* value
Comments	N/A

Data/Parameter	RB
Units	No unit
Description	Proportion of *vPVCs* contributed to the pooled *Risk Buffer*
Equations	Equation 6.2
Source	PV Climate Project Requirement 3.11.3
Value	0.2
Justification of choice of data or description of measurement methods and procedures applied	See PV Climate Project Requirement v5.2
Purpose of Data	Calculation of *vPVCs*
Comments	N/A

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13 Appendices

13.1 Organic soil

As per IPCC (2006), soils are characterized as organic if characteristics 1 and 2, or characteristics 1 and 3 below are met.

1. Thickness of 10 cm or more. A horizon less than 20 cm thick must have 12 percent or more organic carbon when mixed to a depth of 20 cm;
2. The soil is never saturated with water for more than a few days, and contains more than 20 percent (by weight) organic carbon (about 35 percent organic matter);
3. The soil is subject to water saturation episodes and has either:
    I.) At least 12 percent (by weight) organic carbon (about 20 percent organic matter) if it has no clay; or
    II.) At least 18 percent (by weight) organic carbon (about 30 percent organic matter) if it has 60 percent or more clay; or
    III.) An intermediate, proportional amount of organic carbon for intermediate amounts of clay.

13.2 Soil disturbance

Table 3. List of cropland and grassland in which soil disturbance is restricted based upon AR-ACM0003 v.2.0

Region	Land use	Management	Inputs
	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
			High without manure

Region	Land use	Management	Inputs
Temperate, cold, moist	Long-term cultivated cropland	Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
			High without

Region	Land use	Management	Inputs
			High with manure
		No-till	High without manure
			High with manure
	Long-term cultivated cropland	No-till	High with manure
		Full tillage	High with

Temperature / Moisture Regime	Management	Inputs
Boreal	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, dry	Improved	All
	Non-degraded	All
Tropical, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, montane	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, wet	Improved	All
	Non-degraded	High
	Moderately degraded	High