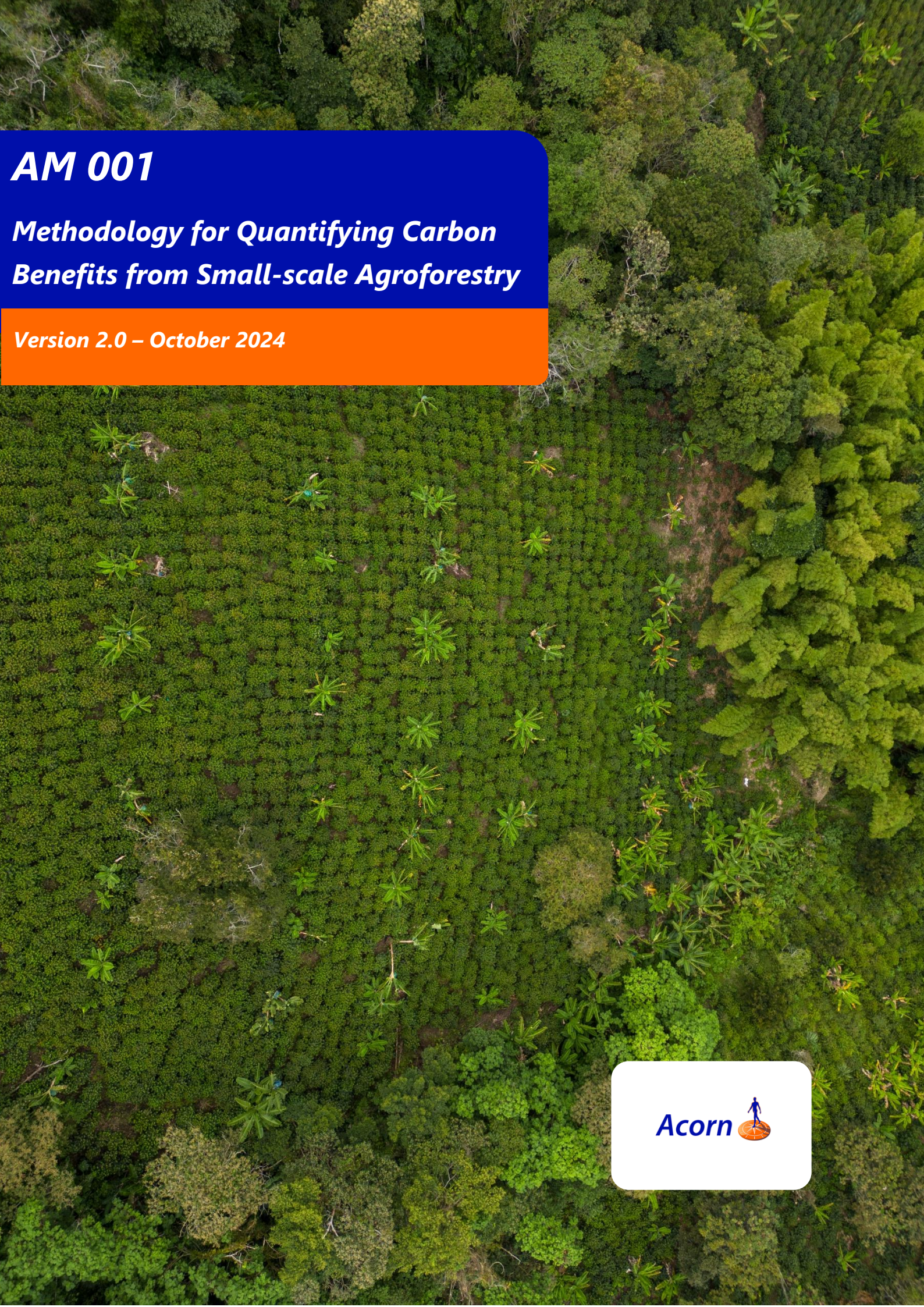

AM 001

Methodology for Quantifying Carbon Benefits from Small-scale Agroforestry

Version 2.0 – October 2024

Acorn

Contents

1 Summary

This methodology is a continuation of the *Quantifying Carbon Benefits from Small-scale Agroforestry Methodology version 1.0*. Both versions (version 1.0 and this version 2.0) of this methodology describe the procedures for measuring change in *carbon stock(s)* and calculating the amount of carbon removals from the atmosphere by adopting *agroforestry* practices. Version 2.0 is designed to sharpen further developments amongst others:

- advancing applicability conditions;
- including complementary modules that describe in detail the model calibration strategy;
- integrating procedures for compensating *harvesting* and *silvopastoral projects* in the carbon calculations;
- adding the contribution of *Soil Organic Carbon (SOC)*;
- elaborating further on the methods for estimating *Aboveground Biomass* and pre-project trees analysis using data-driven approaches.

This methodology can be applied to measure realized *carbon benefits* (*ex-post*) and is not designed to calculate expected *carbon benefits* (ex-ante). The approach quantifies carbon sequestered in different *carbon pool(s)* between two points in time.

This methodology is applicable to all *Acorn projects* that implement *agroforestry* practices on smallholder farms that are not on *wetlands*. To estimate the change in *Aboveground* and *Belowground Biomass* attributable to an *Acorn project interventions* between two points in time, the methodology incorporates direct measurement of trees in *sample plots*, as well as satellite imagery that is interpreted using models derived from *sample plot* data from the *ecoregion* within which the *Acorn project* is located.

This methodology stems from the "*Acorn program*" founded by Rabobank. A related "Acorn Framework" has been developed in close collaboration with the Plan Vivo Foundation to describe project requirements. Under the *Acorn program*, *carbon benefits* are calculated following this approved methodology and *Carbon Removal Units (CRUs)* representing those *carbon benefits* are issued. This methodology is designed following the Plan Vivo PV Climate Methodology requirements V1.1.

2 Sources

Where applicable, this methodology applies the following program-related modules/tools:

- **AM-002** Tool for Performing Deforestation Assessment on Small-scale Agroforestry v1.0
- **AM-003** Module for Ground Truth Sampling v1.0
- **AM-004** Module for Model Development, Calibration, Validation and Application v1.0
- **AM-005** Module for Pre-project Woody Biomass Modeling for Small-scale Agroforestry v1.0
- **AM-006** Module for Performing Leakage Assessment of Carbon Benefits on Small-scale Agroforestry v1.0
- **AM-007** Module for Performing Uncertainty Estimation of Carbon Benefits on Small-scale Agroforestry v1.0
- **AM-008** Module for Performing Partial Felling and Harvesting Estimation of Carbon Benefits on Small-scale Agroforestry v1.0
- **AM-009** Module for Contributions of Small-scale Agroforestry to Soil Organic Carbon Sequestration v1.0
- **AM-010** Module for Emissions from Livestock and Manure Decomposition for Small-scale Agroforestry v1.0

This methodology applies procedures from the following existing methodology and tools, references can be found in Section 13;

- **AR-TOOL02** Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities v1.0
- **AR-TOOL14** Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities v4.2
- **CDM-TOOL21** Demonstration of additionality of small-scale project activities v13.1
- **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

Definitions used in this methodology follow the latest version of the Acorn Glossary available on the Acorn website.

4 Applicability conditions

4.1 Project interventions

This methodology is applicable to all *Acorn 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. *Acorn project interventions* must meet the *agroforestry* definition (see the latest Acorn Glossary), and any trees planted are to be *native* or *naturalized species*.
2. *Project areas* must not have been deforested within 5 years prior to the start of the *Acorn Project Period* (see **AM-002**).
3. *Acorn project interventions* must not take place on *wetlands*.
4. Additional trees would not be planted without the *Acorn project interventions*.
5. *Acorn project interventions* must not (significantly >5%) increase the use of synthetic (nitrogen-containing) fertilizers relative to the *baseline scenario*.
6. *Acorn project interventions must not engage in* slash-and-burn activity or use *heavy machinery* for site preparation or management.
7. *Soil disturbance* attributable to the *Acorn project interventions* must not occur on more than 10% of the *plot* that falls within either of the following categories of land:
   - Land containing organic soils (see Section 14.1)[1];
   - Land which, in the baseline scenario, is subjected to the land-use and practices and inputs described in section 14.2.

Applicability conditions 1, 2, 3 and 4 ensure that *Acorn project interventions* applying this methodology fall within the eligible category of *Acorn 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 Acorn Framework.

[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*.

Conditions 5, 6 and 7 safeguard that carbon emissions, from synthetic fertilizer, *heavy machinery* and *soil disturbance*, are likely to be insignificant (less than 5% of the expected *carbon benefits*) and can be conservatively excluded from the carbon removal calculations.

4.2 Certificate type

If this methodology is applied, *ex-post carbon benefits* can be claimed. In the case of *Acorn program* these credits are referred to as *CRUs*. All *Acorn projects* follow the same approach and quality standard as per the Acorn Framework and this methodology. On a sample basis projects are validated and *CRUs* are verified according to the approved "*Acorn Validation and Verification Cycle - Sampling Approach and Program Certification*" (accessible on the Acorn website). The *Certifier* has the authority to randomly select *plots (of an Acorn project)* for *validation* and *verification* while safeguarding the biomass variance at plot selection. This strategy can be used as a reference for selection. The *Certifier* provides oversight and quality control by fixed assessment stages per project. Within the *Acorn program*, *CRUs* may be issued after *Certifier* approval.

5 Carbon pools and emission sources

The following *carbon pools* and emission sources are considered when assessing the *carbon baseline* and project removals. Due to the nature of eligible projects to which this methodology applies, being small-scale *agroforestry* projects, some *carbon pools* and emission sources are excluded as the potential carbon release from such *carbon pools* and emission sources caused by the *Acorn project interventions* are considered insignificant to the total expected *carbon benefits* of an *Acorn project*.

Table 1. Carbon pools

Carbon pool	Included/excluded	Justification
Aboveground woody *biomass*	Included	A *carbon pool* expected to be significantly impacted by *Acorn project interventions*
Belowground woody *biomass*	Included	A *carbon pool* expected to be significantly impacted by *Acorn project interventions*
Aboveground non-woody *biomass*	Excluded	Not significantly impacted by *Acorn project interventions*, conservatively excluded
Belowground non-woody *biomass*	Excluded	Not significantly impacted by *Acorn project interventions*, conservatively excluded

Litter	Excluded	May be impacted as a result of *Acorn project interventions*, conservatively excluded
Deadwood	Excluded	May be impacted as a result of *Acorn project interventions*, conservatively excluded. The *baseline scenario* is limited to agricultural land, so there is limited potential for removal in this pool
SOC	Optional	*This carbon pool* is likely to increase as a result of *Acorn project interventions*. May be included when applying Module **AM-009**
Harvested wood products	Excluded	May be impacted as a result of *Acorn project interventions*, conservatively excluded

Table 2. Emissions sources

Emission sources	Included/excluded	Justification
Nitrogen fertilizers (N_2O)	Excluded	Emissions from this source are expected to be unaffected or reduced by *Acorn project interventions*, conservatively omitted
Nitrogen fixing species (N_2O)	Excluded	Emissions from the nitrogen fixing species in an small-scale *agroforestry* system is considered limited, conservatively omitted
(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, conservatively omitted
Fossil fuel use (CO_2)	Excluded	Not significantly impacted by *Acorn project interventions*. The use of *heavy machinery* is considered unlikely in small-scale *agroforestry* and not promoted for site preparation or management within *Acorn projects,* conservatively omitted
Enteric fermentation (CH_4)	Optional/Included for silvopastoral activities	Not significantly impacted by *Acorn project interventions* for non-*silvopastoral projects*, where presence of ruminant animals is considered limited at small-scale *agroforestry*. For *silvopastoral*

		projects, this emissions source should be included when applying Module **AM-010**
Manure decomposition (CH_4, N_2O)	Optional/Included for silvopastoral activities	Not significantly impacted by *Acorn project interventions* for non-*silvopastoral projects*, where presence of ruminant animals is considered limited at small-scale *agroforestry*. For *silvopastoral projects*, this emissions source should be included when applying module **AM-010**
Soil methanogenesis (CH_4)	Excluded	Emissions from this source are expected to be unaffected or reduced by *Acorn project interventions*, conservatively omitted (Wang N, et al,. 2023)

6 Baseline scenario and additionality

Local Partners, with support of Acorn, must determine the most likely land use and land management practices in a *project region*, over a period of at least 10 years, in the absence of the *Acorn project interventions* using **AR-TOOL02** and reported in the *carbon baseline* section of the *Acorn Design Document*. The *baseline scenario* must be (re-) assessed against the requirements in the Acorn Framework.

Additionality of the *Acorn project interventions* must be determined using a barrier analysis as defined by **CDM-TOOL21** *Demonstration of additionality of small-scale project activities v13.1* or **AR-TOOL02** *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities v1.0*.

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

Local Partners, with support of Acorn, must re-assess both the *baseline scenario* and *additionality* of an *Acorn project* at least every 10 years throughout the *Crediting Period*.

7 Pre-project tree adjustment

CRUs may only be generated on *biomass* increase that results from the *Acorn project interventions*, therefore *biomass* considered existing before the start of the *Acorn project interventions* should be adjusted for.

The amount of *biomass* present within the *project area* prior to the *Acorn Project Period*, its projected *biomass* contribution, as well as the associated *uncertainty* ($AdjU_{EETBy}$), are

determined following the methodology explained in module **AM-005**. If the estimated increase from existing *biomass* (*$EETB_y$)* plus the *uncertainty* is 10% or less no adjustment needs to be applied. For any value greater than 10%, the adjustment factor (*AdjB*) value described in Table 1 in module **AM-005**.

8 Leakage adjustment

The *leakage* value per *Acorn project* is calculated using data from Global Forest Watch or alternative global forest inventory data sources. This is combined with data on expected productivity loss collected from *Smallholder Farmers*. *Leakage* is estimated within a buffer zone extending 5 kilometers. The *leakage* calculation follows the methodology explained in module **AM-006**.

9 Uncertainty adjustment

The *uncertainty* value per *Acorn project* is calculated following the methodology explained in module **AM-007**. If *Aboveground Biomass* in a *plot* is estimated using satellite imagery, the *uncertainty* in the temporal change of the *Aboveground Biomass* in a *plot* can be calculated following module **AM-007**.

10 Partial felling & Harvesting practices

Acorn projects are allowed to have *partial felling* and/or *harvesting* activities within the *Acorn project interventions*. The calculation of *Aboveground Biomass* due to *harvesting* follows the methodology explained in module **AM-008**.

11 Carbon calculations

11.1 Ecoregion(s)

Project area(s) within *Acorn program* 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 (**AM-003**). By default, each *ecoregion* should at least collect a minimum of 30 *sample plots* at the start of the *Acorn project interventions*. In the years thereafter, for each *ecoregion*, a minimum of 30 additional *sample plots* need to be collected at least every 5 years and applied to enhance model performance. Up to 300 *plots* within a *project area* can belong

to a non-calibrated *ecoregion* if the *plots* that are located within a neighboring calibrated *ecoregion*, have the same *Agroforestry Design*, and are within the same calibration range.

11.2 Root:shoot ratio

Root:shoot ratio is defined as the ratio of *Belowground Biomass* to *Aboveground Biomass*. If no transparent, scientific and verifiable information on local context is available to justify a specific root:shoot ratio, an appropriate *project 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 an *Acorn project* includes multiple *ecoregions*, a weighted average value will be assigned to the *Acorn project* for *biomass* below 125 t/ha. The category exceeding 125 t/ha falls outside of Acorn's scope, 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. (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 calculated the *Belowground Biomass* as shown in Equation 1.

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

Equation 1

Where:

$BGB_{\Delta,y}$ = Change in *Belowground Biomass* in year y (tonne/ha)

$AGB_{\Delta,y}$ = Change in *Aboveground Biomass* in year y (tonne/ha)

R = Root:shoot ratio

11.3 Carbon Removal Units

All carbon models are developed from a combination of *sample plot* measurements and satellite imagery and are specific to an *ecoregion*. Equation 2 describes how to calculate the number of *CRUs* that can be generated from the delta in various carbon pools and emission sources. First, the adjustment factors (for *leakage*, *pre-existing biomass* and *uncertainty*) are

[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

deducted from the *carbon stocks*, after that the conversion from carbon to carbon dioxide equivalent is made and finally, the change in livestock emissions and the *bufferpool* are subtracted. Quantification for estimated emissions from silvopastoral *Acorn project interventions* can be found in module **AM-010** and is optionally included in Equation 2 below.

$$CRU = ((((AGB_{\Delta,y} + BGB_{\Delta,y}) \cdot CF + SOC_{\Delta,y} - AdjL) \cdot (1 - AdjB) \cdot (1 - AdjU) \cdot C) - (LE_{\Delta,y})) \cdot (1 - BP)$$

Equation 2

Where:

CRU = Carbon Removal Unit (t CO_2e)

$AdjL$ = Adjustment factor for *leakage* (tonne Carbon; see **AM-006**)

$AdjB$ = Adjustment factor for *pre-existing biomass* (% see **AM-005**)

$AdjU$ = Adjustment factor for *uncertainty* (% see **AM-007**)

CF = Carbon fraction of *biomass* = 0.47

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

$LE_{\Delta,y}$ = Change in livestock greenhouse gas emissions for a *plot* between year y and upper bound greenhouse gas emissions in the baseline year (t CO_2e/ha; see **AM-010**)

BP = *Buffer pool* percentage

CRUs can be calculated up to 1.5 year, depending on the measuring date, prior to *plot* onboarding. Negative *biomass* value within the first measured period can be assigned to *plot* preparation and other agricultural practices that allow the *Smallholder Farmer* to be onboarded to the *Acorn project*. After *CRU* generation, negative *biomass* values need to be compensated by additional *biomass* growth before new *CRU* generation or by the *buffer pool* after a *reversal event*.

12 Parameters

Data/Parameter	$AdjB$
Units	%
Description	Adjustment factor for *pre-existing biomass*
Equations	N/A
Source	AM-005 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	$AdjL$
Units	Tonne Carbon
Description	Adjustment for *leakage*
Equations	Equation 2
Source	AM-006
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	Input value for determining the related adjustment factor (*AdjL*)
Comments	N/A

Data/Parameter	$AdjU$
Units	%
Description	Adjustment factor for uncertainty on project level
Equations	Equation 6
Source	AM-007
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	To determine the project-based adjustment factor applied equally to all plots.
Comments	N/A

Data/Parameter	$AGB_{\Delta,y}$
Units	Tonne/ha
Description	Change in *Aboveground Biomass* in year y
Equations	Equation 1 and Equation 2
Source	Satellite imagery; *Aboveground Biomass* is estimated using a machine learning model (Shen et al., 2022) and is explained in AM-004 and AM-006
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Satellite imagery is used as input for Acorn *biomass* model to estimate biomass at two moments in time AGB_y *and* AGB_{y-1}. $AGB_{\Delta,y} = AGB_y - AGB_{y-1}$.
Purpose of Data	Estimation of *Aboveground Biomass* contributions to total project removals
Comments	N/A

Data/Parameter	BP
Units	Percentage (%)
Description	*Buffer pool is 20%*
Equations	Equation 3
Source	Acorn Framework
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	*Buffer pool* calculations in line with market practice
Purpose of Data	*CRUs* set aside for *reversal events*
Comments	N/A

Data/Parameter	C
Units	No unit
Description	Conversion from carbon to carbon dioxide
Equations	Equation 3

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 3
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	$LE_{\Delta,y}$
Units	t CO_2e/ ha
Description	Change in livestock greenhouse gas emissions for a *plot* between year y and upper bound greenhouse gas emissions in the baseline year
Equations	Equation 1
Source	AM-010 Equation, surveys or inventory of *project areas* and IPCC, 2019
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	A method in line with international standards.
Purpose of Data	Estimation of livestock greenhouse gas emissions from *enteric fermentation* and *manure decomposition*

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	$SOC_{\Delta,y}$
Units	Tonne/ha
Description	Change in soil organic matter in year y (t CO_2e) derived from *Aboveground* and *Belowground* values
Equations	Equation 2
Source	Module AM-009
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	This is calculated from the estimated change in *biomass*, see Module AM-009.
Purpose of Data	Estimation of *SOC* contributions to total project removals
Comments	N/A

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14 Appendices

14.1 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.

14.2 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
Boreal	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure
Temperate, cold, dry	Long-term cultivated cropland	Full tillage	High with manure
		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
		No-till	Medium
			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
		No-till	High without manure
			High with manure
Temperate, warm, dry	Long-term cultivated cropland	Full tillage	High with manure
		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
		No-till	Medium
			High without manure
Temperate, warm, 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
		No-till	High without manure
			High with manure
Tropical, dry	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	Medium
			High without manure
			High with manure
		No-till	All
Tropical, moist	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure

Region	Land use	Management	Inputs
			High with manure
		No-till	High without manure
			High with manure
Tropical, montane	Long-term cultivated cropland	No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure
			High with manure
		No-till	Medium
			High without manure
			High with manure
Tropical, wet	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure
			High with manure
		No-till	High without manure
			High with manure

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