

METHODOLOGICAL DOCUMENT

AFOLU SECTOR

BCR0001 Quantification of GHG Emission Reductions **GHG REMOVAL ACTIVITIES**

BIOCARBON REGISTRY®

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Table of contents

1	Introduction	7
1.1	Objectives	7
2	Source	8
3	Version and validity	8
4	Scope	8
5	Applicability conditions	8
6	Normative references	9
7	Terms and definitions	9
8	Carbon reservoir and GHG sources	16
8.1	Carbon reservoirs	16
8.2	Emission sources and GHGs selected for accounting	16
9	Eligible areas for GHG projects in the AFOLU sector	17
9.1	Requirements of geographic information for the eligibility analysis	18
10	Adding areas after validation	18
11	Identification of the baseline scenario and additionality	19
11.1	Baseline scenario	19
11.2	Additionality analysis	21
12	Conservative selection of default values	28
13	Stratification	28
14	Uncertainty management	29
14.1	Difference of two independent stock estimations	30
14.2	Direct estimation of change by re-measurement of sample plots	31
15	GHG removals by sinks	34
15.1	Baseline net GHG removals by sinks	34

15.2	Actual net GHG removals by sinks.....	35
15.2.1	Trees and shrubs	37
15.2.2	Deadwood and litter.....	38
15.2.3	Soil organic carbon (SOC)	42
15.3	Leakages	49
15.4	Net anthropogenic GHG removals by sinks	50
16	Monitoring plan	50
16.1	Monitoring of the project boundaries.....	51
16.2	Monitoring of the implementation of project activities	51
16.3	Site management and biomass growth monitoring	52
16.3.1	Stratification and sampling design.....	53
16.3.1.1	Stratification	53
16.3.1.2	Sampling plots	53
16.3.1.3	Size of plots or sampling units.....	53
16.3.1.4	Sampling size	53
16.3.1.5	Calculation of sample plots number	55
16.3.1.6	Allocation of sample plots.....	56
16.3.1.7	Monitoring frequency	56
16.3.1.8	Measuring and estimating changes in carbon contents.....	56
16.4	Monitoring of the quantification of project removals.....	57
16.5	Quality control and quality assurance procedures	58
16.5.1	Field data verification.....	58
16.5.2	Review of information processing	59
16.5.3	Data recording and storage system	59

List of tables

Table 1. Carbon reservoirs selected for the accounting of carbon stock changes	16
Table 2. Emission sources and GHGs selected for accounting	16
Table 3. Quality discounts and applicability of GHG estimation models	29
Table 4. Uncertainty discount factors	33
Table 5. Parameters dead wood and litter	38
Table 6. Default values used for dead wood and litter	40
Table 7. Default reference SOC stocks (SOCREF) for mineral soils(tC ha ⁻¹ in 0-30 cm depth).....	44
Table 8. Default factors for relative changes in organic C stocks due to crop management activities (net effective over 20 years)	45
Table 9. Relative stock change factors for different levels of nutrient input on cropland (net effect over 20 years)	46
Table 10. Relative stock change factors (f_{LU} , f_{MG} , and f_{IN}) for grassland management (net effect over 20 years)	47
Table 11. Variables to monitor sites establishment	52
Table 12. Parameters determined by the tool for sampling	55

Acronyms and abbreviations

AFOLU	Agriculture, forestry, and Other Land Use
A/R (AR)	Afforestation/Reforestation
AR-ACM	Afforestation/Reforestation Large-scale CDM Consolidated Methodology
CBR	Cost-benefit ratio
CDM	Clean Development Mechanism
CH ₄	Methane
CLC	CORINE Land Cover
CO ₂	Carbon dioxide
EMBI	Emerging Markets Bonds Index
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gases
IIR	Internal Rate of Return
IPCC	Intergovernmental Panel on Climate Change
N ₂ O	Nitrous oxide
NVP	Net Present Value
RRR	Required Rate of Return
SOC	Soil organic carbon
UNFCCC	United Nations Framework Convention on Climate Change
VCC	Verified Carbon Credits

1 Introduction

This Methodology provides the best practices related to procedures, equations, parameters, and data to quantify GHG emission reductions attributable to project activities. Its target audiences are GHG project holders in the AFOLU sector (GHG removal activities)

This Methodology considers organic soil disturbance restrictions and some land-use practices that determine carbon stock changes, depending on management actions, climatic conditions, and soil types.

Holders of GHG projects applying this Methodology may choose to exclude or include quantification of some of the carbon pools considered in activities related to Agriculture, forestry, and other land uses.

The Methodology determines aspects related to identifying the baseline scenario, additionality considerations, stratification, GHG removal by sinks (including leakage), and the monitoring plan, considering quality control and quality assurance procedures.

With the requirements and descriptions included in this methodological document, the holders of GHG projects in the AFOLU sector have complete and detailed guidance for designing and implementing GHG emission reduction or removal projects.

1.1 Objectives

The objectives of this methodological document (from now on referred to as Methodology) are:

- (a) provide requirements for quantification of GHG Emission Reductions from GHG removal activities;
- (b) present the methodological requirements for the baseline identification for GHG removal activities;
- (c) endow the methodological requests to demonstrate additionality of GHG removal activities;
- (d) Describe monitoring requirements and follow-up of GHG projects in the AFOLU sector (GHG removal activities);

2 Source

This Methodology is based¹ on the CDM Methodology²: "AR-ACM0003. *A/R Large-scale Consolidated Methodology. Afforestation and reforestation of lands except wetlands. Version 02.0 AR*³ and CDM tools, applicable to this projects' type.

3 Version and validity

This document constitutes Version 3.0. April 13, 2022.

The present version may be adjusted periodically, and intended users shall ensure that they are using the document's updated version.

4 Scope

This document constitutes a methodology of baseline, quantification of emission reductions, and monitoring of GHG projects.

This Methodology is limited to the following categories of GHG projects in the AFOLU sector:

- (a) GHG removal activities

The project holders shall use this Methodology for the initiatives classified as GHG projects to be certified and registered with the Voluntary Carbon Market Standard. BCR Standard Projects.

5 Applicability conditions

This Methodology is applicable under the following conditions:

- (a) The areas in the project boundary shall not correspond to the forest category (according to the national definition adopted by the country in which the project activity is proposed), nor natural vegetation different to a forest, at the beginning of project activities and not five years before the project start date⁴;

¹ Although this document does not correspond to an identical transcription of the AR-ACM0003 methodology, it considers the fundamental elements that constitute it.

² Approved by the Executive Board of the Clean Development Mechanism, United Nations Framework Convention on Climate Change.

³ Available in: <https://cdm.unfccc.int/methodologies/DB/C9QS5G3CS8FW04MYXDFQDPXWM4OE>

⁴ Except for cases in which the activities in the project correspond to restoration, rehabilitation and recovery.

- (b) The areas in the project boundary do not fall in the wetland category⁵;
- (c) The areas in the project boundary do not contain organic soils⁶;
- (d) Carbon stocks in soil organic matter, litter, and deadwood decrease or remain stable, in the absence of project activities, that is, relative to the baseline scenario;
- (e) Flood irrigation is not used;
- (f) The effects of drainage are negligible, so GHG emissions, other than CO₂, can be omitted;
- (g) Soil disturbances due to project activities, if any, are carried out following appropriate soil conservation practices and have not been repeated for less than 20 years.

6 Normative references

The following references are indispensable for the implementation of this Methodology:

- (a) Voluntary Carbon Market Standard. BCR StandardProjects, in its most recent version;
- (b) IPCC 2003, 2006 and 2019 Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, forestry and other land use;
- (c) The national legislation in force, related to forestry activities and permanent tree crops and GHG projects, or that which modifies or updates it.;
- (d) The guidelines, orientations, and guides by BIOCARBON REGISTRY[®], in the framework of projects in the AFOLU sector.

7 Terms and definitions

Additionality

It is the effect of the project activity to reduce anthropogenic GHG emissions below the level that would have occurred in the absence of the GHG project or project activity.

⁵ The Ramsar Convention on Wetlands defines wetlands as "areas of marsh, fen, peat, and or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Ramsar, 1971).

⁶ According to FAO (definition adopted by IPCC), the organic soils are soils with organic carbon content equal to or greater than 12%.

In the AFOLU sector, for projects other than REDD+, additionality is the effect of the project activity to increase actual net GHG removals by sinks above the sum of carbon stock changes in carbon pools within the project boundary that would have occurred in the absence of the project activity.

Source: Adapted from CDM Glossary.

Agricultural lands

Agricultural territories are those lands dedicated mainly to the production of food, fiber, and other industrial raw materials, whether they are useful or not for cultivation, cattle grazing, crop rotation, or fallow. It includes areas devoted to permanent and temporary crops, pasture areas, and different agricultural zones, where livestock can occur with agriculture.

Agroforestry culture

Areas occupied by arrangements or combinations of crops of different species, with others of herbaceous, shrub, or tree habits, where the main characteristic of the coverage is that the increase in detail does not imply the subdivision into pure units because these share the same area, alternated by furrows or rows of trees with crops or trees with grasses.

AFOLU (Agriculture, Forestry and Other Land Use)

The sector comprises either greenhouse gas emissions or removals attributable to project activities in agriculture, forestry, and other land uses.

Baseline or reference scenario

The baseline or reference scenario represents the sum of variations in carbon stocks, included within project boundaries, in the absence of the project activities.

Carbon fraction

Tons of carbon per ton of dry biomass.

Denitrification

It is the biological transformation of nitrate into nitrogen gas, nitric oxide, and nitrous oxide. Denitrification can occur in two ways. The first is the differentiated reduction of nitrate under anoxic conditions. The second is, under aerobic conditions, denitrification follows the assimilative or nitrogen accumulation pathway in biomass.

Ecological Restoration

According to the Society for Ecological Restoration (SER), ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed.⁷

Eligible areas

Areas that meet the absence of forest or natural cover other than a forest, on the reference dates established by the BCR STANDARD.

Geographical limits of the Project's area are not in the forest category⁸, or natural cover other than the forest, neither at the beginning nor five years before the project starts.

For areas in which ecological restoration, ecological rehabilitation and ecological recovery activities are proposed, eligible areas should be determined by land use analysis for the same reference dates. However, these should not necessarily demonstrate compliance with the forest definition.

If the eligibility analysis is included in the project boundary's total since the validation, the holder of the GHG project shall demonstrate the eligibility five years before and at the start date of the project activities.

If areas are subsequently included, which were not included in the initial analysis (in validation), the land cover for each plantation area shall be identified in every one of the dates on which activities in the forestry activities are established.

Forestry plantation

They are covers constituted by plantations of arboreal vegetation, made by the man's direct intervention with forest management aims. In this process, forest stands start by planting and, when applicable to seeding during the forestation or reforestation process to produce wood (commercial plantations) or environmental goods and services (protective plantations).

GHG Project (Greenhouse gas project)

activity or activities that alter the conditions of a GHG baseline and cause GHG emissions reductions or GHG removals.

[SOURCE: ISO 14064-3:2019(en), 3.4.1.]

⁷ <https://www.ser.org/>

⁸ In accordance with the national definitions of forest and natural vegetation cover other than forest

GHG Project holder (greenhouse gas project proponent)

individual or organization that has overall control and responsibility for a GHG project.

Note 1 to entry: The term “project proponent” is also used synonymously in the text.

[SOURCE: ISO 14064-2:2019(en), 3.3.2]

GHG removal activities

These are GHG mitigation actions in the AFOLU sector based on agricultural and forestry activities. These may include: silvopastoral systems (pastures and planted trees), agroforestry systems (agroforestry crops), commercial plantations (forest plantations), and other landscape management tools, as well as oil palm and other crops, as long as they are developed in areas other than natural forest or natural vegetation cover other than forest.⁹

GHG removal activities may also include actions leading to the restoration of degraded ecosystems, such as: (a) ecological restoration, (b) ecological rehabilitation and, (c) ecological recovery.

Greenhouse gas reservoir (GHG reservoir)

component, other than the atmosphere, that has the capability to accumulate GHGs, and to store and release them.

Note 1 to entry: The total mass of carbon contained in a GHG reservoir at a specified point in time could be referred to as the carbon stock of the reservoir.

Note 2 to entry: A GHG reservoir can transfer GHGs to another GHG reservoir.

Note 3 to entry: The collection of a GHG from a GHG source before it enters the atmosphere and storage of the collected GHG in a GHG reservoir could be referred to as GHG capture and GHG storage.

[SOURCE: ISO 14064-3:2019(en), 3.3.5]

Landscape management tools (LMT)

Landscape management tools are landscape elements that constitute or enhance habitat, increase functional connectivity, or simultaneously fulfill these functions for native biodiversity. Landscape management tools may include biological and conservation corridors and living fences.

⁹ The names in parentheses correspond to the definitions contained in CORINE Land Cover. See Glossary of terms.

Corridors (biological and conservation) are landscape management tools that encourage movement and genetic exchange between local populations spatially isolated because of habitat fragmentation and loss. They can be constituted following natural routes of dispersion and migration, such as watercourses or restoration strategies over open areas. Biological corridors can be remnant when the connection between preserved or restored forest patches when they are re-established.

Live fences are crucial for increasing structural connectivity, resource provisioning, and reducing fence maintenance costs. We seek to generate the most extensive and most efficient possible connections of forest fragments with living fences, such as in minimal areas, without altering existing productive activities on a large scale. Living fences reduce pressure on forests by decreasing the demand for fancy figured woods.

Leakages

Those are the potential emissions that would occur outside the project boundaries due to the GHG project's activities. Leakage means the net change in anthropogenic emissions by sources of greenhouse gases (GHG) that occurs outside the project boundary and is measurable and attributable to the project activity.

Natural Forest (Forest)

"Forest" is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest¹⁰.

The GHG project holder must demonstrate the consistency of the eligibility analysis, in accordance with national forest definitions, following the criteria defined by the UNFCCC in its decision 11/COP.7.

Oil palm crop

The palm crop is the cover composed of oil palm (*Elaeis* spp.), a perennial plant with a solitary trunk and pinnate leaves belonging to the Arecaceae family, which can reach heights of up to 12 m.

¹⁰ UNFCCC. The Marrakesh Accords. Available in <https://unfccc.int/sites/default/files/resource/docs/cop7/13a01.pdf>

Organic soils

According to FAO (definition adopted by IPCC)¹¹, organic soils are organic carbon content equal to or greater than 12%. Organic soils (e.g., peat and manure) have at least 12 to 20 percent organic matter by mass and thrive under poorly drained wetlands conditions.

Organic soils are identified based on criteria 1 and 2, or 1 and 3 listed below:

1. The thickness of the organic horizon is greater than or equal to 10 cm, and less than 20 cm. It has 12 percent or more organic carbon when mixed to a depth of 20 cm.
2. Water never saturates the soils for more than a few days, and they shall contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).
3. Soils in a saturation episode have either:
 - a) At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soils have no clay;
 - b) At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soils have 60% or more clay; or
 - c) An intermediate proportional amount of organic carbon, for intermediate amounts of clay.

Permanence

The condition resulting from the project activities whereby the system implemented within its limits extends continuously and over time, removing GHG from the atmosphere.

Planted trees and crops

The area occupied by spatial arrangements combines crops and tree plantations (wood, firewood, fruit trees, resins, among others). Its main characteristic is that its increase in detail does not imply the subdivision into pure units, because they are combined in the same area, alternating trees' rows with crops.

Planted trees and grasses

The area occupied by spatial arrangements combines pastures, destined for livestock, tree plantations destined for tree plantations (wood, firewood, fruit trees, resins, and others.). It is the so-called silvopastoral system. This coverage's main characteristic is that the increase

¹¹ Hiraishi, Takahiko, et al. "2013 supplement to the 2006 IPCC guidelines for national greenhouse gas inventories: Wetlands." *IPCC, Switzerland* (2014).

in detail does not imply the subdivision into pure units because these shares the same area alternating by furrows or rows of trees with pastures.

Project Start date

The start date of GHG projects is when the activities resulting in effective GHG emission reductions begin.

For GHG projects, based on GHG removal forestry activities and oil palm cultivation, this is the start date of site preparation, cultivation establishment, restoration activities, or other actions related to the mitigation project activities.

For REDD+ projects, the start date begins activities proposed by the Project to demonstrate reduced emissions from deforestation and forest degradation. It may be, for example, the start of forest management strategies or forest resource conservation plans. In other words, concrete actions to reduce deforestation.

NOTE: The documentary evidence may include contracts for the provision of services related to the establishment of forestry or crops activities, acquisition of plant material invoices, registration in activity execution sheets, or employing of labor, among others.

Source, sink or carbon reservoir-related

Source sink or reservoir of GHG with flows of energy or materials to the interior, exterior or within the Project.

Vegetation cover, different from natural forest (Scrub and/or herbaceous vegetation Associations)

This coverage includes a vegetation group of a natural type and a natural succession's result, whose growth habit is shrubby and herbaceous, developed on different substrates and elevational levels, with little or no anthropic intervention. According to CORINE Land Cover legend, this class includes other cover types such as areas covered by mainly shrubby vegetation with an irregular canopy, shrubs, palms, vines, and low growing vegetation.

Wetlands

The Ramsar Convention on Wetlands defines wetlands as "*areas of marsh, fen, peat, and or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.*" (Ramsar, 1971)¹².

¹² Available in: https:// Ramsar.org/documents?field_quick_search=2550

IPCC defines wetlands as: "Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories. Managed wetlands are restricted to wetlands where the water table is artificially changed (e.g., drained or raised) or those created through human activity"¹³.

8 Carbon reservoir and GHG sources

8.1 Carbon reservoirs

The Intergovernmental Panel on Climate Change (IPCC) foresees the estimation of carbon stocks changes in the following reservoirs: above-ground biomass, below-ground biomass, deadwood, litter and soil organic carbon (SOC). However, the holders of GHG projects may choose not to consider one or more carbon pools as long as they provide transparent and verifiable information and do not increase GHG emission reductions, quantified by the Project.

The selection of carbon reservoirs to quantify changes in carbon stocks at the project boundaries are shown in *Table 1*.

Table 1. Carbon reservoirs selected for the accounting of carbon stock changes

Carbon reservoir	Selected (Yes/No)	Justification/Explanation
Above-ground biomass	Yes	Carbon stock in this reservoir is expected to increase due to the implementation of the project activity.
Below-ground biomass	Yes	Carbon stock in this reservoir is expected to increase due to the implementation of the project activity.
Deadwood and litter	Optional	Carbon stock in these pools may increase due to the implementation of the project activity.
Soil organic carbon	Optional	Carbon stock in these pools may increase due to the implementation of the project activity.

8.2 Emission sources and GHGs selected for accounting

The emission sources and associated GHGs selected for accounting are shown in *Table 2*.

Table 2. Emission sources and GHGs selected for accounting

Source	GHG	Selected (Yes/No)	Justification/Explanation
Burning of woody	CO ₂	No	CO ₂ emissions due to the burning of biomass are

¹³ https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_07_Ch7_Wetlands.pdf

Source	GHG	Selected (Yes/No)	Justification/Explanation
biomass			not accounted as a change in carbon stock.
	CH ₄	Yes	Burning of woody biomass for site preparation or as part of forest management is allowed under this Methodology.
	N ₂ O	Yes	Burning of woody biomass for site preparation or as part of forest management is allowed under this Methodology.

9 Eligible areas for GHG projects in the AFOLU sector

For activities other than restoration, recovery and rehabilitation, the holder of the GHG project shall demonstrate that the areas at the geographical boundaries of the Project do not correspond to the category of forest, nor to natural vegetation cover other than wood at the start of project activities, nor five years before the project start date.

This demonstration shall be by multi-temporal land cover analysis (on scales 1: 10,000 or higher) for the project start date and five years ago, (counting from the project start date), according to the land use and/or land cover classifications that apply for the country in which the project activities are proposed. Additionally, land cover shall be identified for each planting date of the areas in the project, if the analysis was not developed for all areas in the project, at the validation time.

The cartographic inputs for the identification of land cover/use and the methodological process for the generation of information on land use changes should be based on reliable information, based on defined land use categories, for example, by the IPCC for national inventories of Greenhouse Gases -GHG. These, in turn, should be consistent with the land use categories applicable in the country in which the proposed GHG project is located.

To identify natural vegetation cover other than a forest, the GHG project holder shall use the CORINE Land Cover, or that applicable in the country in which the project is being developed.

On the other hand, for activities other than ecological restoration (including reclamation and rehabilitation), on behalf of the identification and selection of eligible areas, the holder of the project shall provide evidence that the land within the project boundaries, at the beginning of the Project and five years after the start date¹⁴:

¹⁴ Adapted of CDM Tool "A/R Methodological tool Demonstration of eligibility of lands for A/R CDM project activities" Version 2.0. <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-19-v1.pdf>

- (a) it is not covered by forest or natural vegetation cover other than forest; and,
- (b) The land is not a part of a forest area that is temporarily unstocked due to human intervention (e.g., harvesting) or natural causes. It is not covered for young natural stands, which are not expected to reach the forest threshold values applicable to the host Party and the land is not expected to revert to a forest without human intervention.

9.1 Requirements of geographic information for the eligibility analysis

To demonstrate land eligibility, the GHG project holders shall carry out a multi-temporal analysis of satellite images, through which changes in land use coverage following the country's land cover analysis methodologies in which the project activities are proposed.

10 Adding areas after validation

The holders of GHG projects in the AFOLU sector may add areas to the Project under the following conditions:

- a) The project holder shall identify the project expansion area during the validation process and define the criteria for adding new areas;
- b) The default criteria that a new area shall meet to be added to the Project are:
 - i) Comply with the guidelines of the Voluntary Carbon Market Standard. BCR Standard, in their most recent version;
 - ii) Comply with all the provisions in the Methodological document Quantification of GHG Emission Reductions from GHG projects. GHG Removal Activities, in their most recent version;
 - iii) Include emission reduction only for validated project activities¹⁵;
 - iv) Implement activities in the AFOLU sector described in the validated project document;
 - v) Demonstrate that additionality, land tenure, and baseline scenario are consistent with the validated descriptions in the project document;
 - vi) Consider a starting date after the start date of the areas included in the validation.

¹⁵ An activity not included in the validation process cannot be included in a new area.

The GHG project holders (in the AFOLU sector) may add areas to the project, only during the two (2) years following registration in the Program and, demonstrating that both the eligibility condition of the areas and the characteristics of additionality and related to the applicable legislation are met.

11 Identification of the baseline scenario and additionality

11.1 Baseline scenario

The Project holders shall identify the baseline scenario to demonstrate that the Project is additional.

Under the UNFCCC, when selecting the Methodology to determine the baseline scenario of a project in the AFOLU sector, the project holder shall select the most appropriate among the criteria listed below, justifying this choice's convenience.

- (a) Existing or historical changes, as appropriate, in carbon stocks at project boundaries;
- (b) Changes in carbon stocks, within the project boundary, due to land use that represents an attractive course of action considering barriers to investment;
- (c) Changes in carbon stocks within the project boundaries, identifying the most likely land use at the beginning of the Project.

For this methodology's application, it is recommended to use what is stated in literal (c) above. However, the project's holder may select (a) o (b) approaches, if he or she presents appropriate explanation and justification.

The holder of the project shall reliably demonstrate that all the assumptions, justifications, and documentation considered are adequate to identify the baseline scenario.

The project holder shall identify the baseline scenario through the following steps¹⁶:

STEP o. Project start date

The start date of GHG projects is when effective GHG emission reductions begin.

¹⁶ Adapted of "Combined tool to identify the baseline scenario and demonstrate additionality" (Report EB35, Annex 19).

The project holder shall determine the project start date, describe that choice, and present evidence that proves its date. That evidence shall demonstrate that the start date is defined within the five (5) years before project validation starts.

STEP 1. Identification of alternative land-use scenarios

This step consists of identifying the most probable land-use scenarios, which could be the baseline scenario, through the following sub-steps:

Sub-step 1a. Identification of probable land use alternatives in the project areas

Identify realistic and credible land use alternatives in the project areas in the absence of the proposed project activity. The alternatives shall be feasible considering the relevant national or sectoral circumstances and policies, considering historical land uses in the Project's area of influence, economic practices, and economic tendencies in the region. These alternatives shall include at least the following activities:

- (a) Continuation of previous land use (prior to Project);
- (b) Forestry or palm crops.

In this case, the project holders shall demonstrate that the Project increases the rate of establishing crops due to the direct intervention of the project activities¹⁷.

- (c) Other plausible and credible land-use alternatives for location, size, funding, experience requirements, among others, may include alternatives that represent common land-use practices in the region where the Project is located.

Result of sub-step 1a. List of possible land-use alternatives can occur in the project area in the absence of the GHG mitigation sector project's activities.

Sub-step 1b. Consistency of land use alternatives with applicable laws and regulations

National and sectoral policies related to natural resources and activities in the AFOLU sector provide applicable laws and regulations. The project holders shall demonstrate all land-use alternatives identified in sub-step 1a comply with all applicable statutory and mandatory regulatory requirements. If some do not, the holder shall demonstrate that, based on a careful analysis of current practice in the region where the law is mandatory, or regulation applies, non-compliance with those requirements is widespread, that is, prevails in at least 30% of the area of the smallest administrative unit that encompasses the project area.

¹⁷ If the proposed project activity does not lead to an increase in this rate, the project is not additional.

Remove from the land-use scenarios identified in sub-step 1a any land use alternatives that do not comply with applicable mandatory laws and regulations unless you can demonstrate that such alternatives result from systematic failure to comply with the mandatory laws and regulations.

Result of sub-step 1b. List possible land use alternatives that comply with the legislation and mandatory norms and regulations, considering their compliance in the region or country, for national or sectoral policies.

If the list resulting from sub-step 1b is empty or contains only one land-use scenario, the Project is not additional.

11.2 **Additionality analysis**

Once you have obtained a list of likely land-use alternatives ([Section 11.1 above](#)), go to Step 2 (Investment Analysis) or Step 3 (Barrier Analysis), as at least one of these two steps needs to be done to demonstrate the additionality of the Project.

STEP 2. Investment analysis

This step serves the project holder to determine the investment analysis of the possible land-use alternatives identified in the sub-step 1b.

The holder shall determine whether the project activity, without the revenues derived from Verified Carbon Credits (VCC) sale, is economically or finance less attractive than other alternatives. The investment analysis may be carried out like an independent additionality analysis or ensemble with the barrier analysis (Step 3). To perform investment analysis, use the following sub-steps:

Sub-step 2a. Determine the appropriate analysis method

Determine whether to apply simple cost analysis, investment comparison analysis, or benchmark analysis (Sub-step 2b).

If the project activity and the alternatives identified in Step 1 generate no financial or economic benefits other than carbon credits sale-related income, apply the simple cost analysis (Option I). Otherwise, use the investment comparison analysis (Option II) or the benchmark analysis (Option III). Please note those options I, II, and III are mutually exclusive. Therefore only one of them shall apply.

Sub-step 2b. – Option I. Apply simple cost analysis

Document the costs associated with the project activities and show that the Project does not produce financial benefits other than CCV sale income.

If the conclusion is that the Project does not produce any financial benefit, go to Step 4 (Impact of project registration).

Sub-step 2b. – Option II. Investment comparison analysis

Identify the financial indicator most suitable for the project type and decision-making contexts, such as IRR, NPV, payback period, or cost-benefit ratio.

Sub-step 2b – Option III. Benchmark analysis

Identify the financial indicator most suitable for the project type and decision context, such as IRR, NPV, payback period, cost-benefit ratio, or other. For example, the required return rate (RRR) is a suitable indicator for agriculture or forestry investments. Another example is the bank deposit interest rate corrected by the Project's inherent risk or opportunity costs of land, like any expected income from land speculation.

Identify the relevant benchmark value, such as the required rate of return (RRR) on equity. The benchmark represents standard returns in the market, considering the specific risk of the project type, but not linked to the subjective profitability expectation or risk profile of a particular project developer. Benchmarks can be derived from:

- Government bond rates, increased by a suitable risk premium to reflect the private investment or the project type, as substantiated by an independent (financial) expert;
- Estimates of the cost of financing and required return on capital (e.g., commercial lending rates and guarantees required for the country and the type of project activity concerned), based on banker views and private equity investors or funds' required return on comparable projects;
- A company internal benchmark that means a weighted average capital cost of the company is only one potential project developer. E.g., a single entity, physical person, or a company, who is also the project developer, owns or controls the proposed project land. The project developers shall demonstrate that this benchmark has been consistently used in the past, i.e., that project activities under similar conditions developed by the same company used the same benchmark.
- Beta rates of forestry or agricultural industry adjusted with the EMBI (Emerging Markets Bonds Index) of the country in which the Project is developed.

Sub-step 2c. Calculation and comparison of financial indicators (only applicable to options II and III)

Calculate the suitable financial indicator for the project activity, without the financial benefits from the sale of VCC and, in the case of Option II above, for the other alternatives. Include all relevant costs, for example, investment cost, operations and maintenance costs, and all revenues, excluding VCC revenues but including subsidies or fiscal incentives where applicable. In the case of public investors and as appropriate, also include non-market costs and benefits.

Present the investment analysis transparently and provide all the relevant assumptions. Present also the critical economic parameters and assumptions, such as capital costs, lifetimes, discount rate, or capital cost. Justify assumptions in a manner that the VVB can validate them. In calculating the financial indicator, the Project's risks can be included through the cash flow pattern, subject to project-specific expectations and assumptions, e.g., project holders may use insurance premiums to calculate and reflect specific risk equivalents.

Assumptions and input data for the investment analysis shall not differ across the project activity and its alternatives unless differences can be well substantiated.

Present a precise comparison of financial metric for the Project, without the financial benefits from VCC.

Option II (investment comparison analysis): if one of the other alternatives has the best indicator (for example, a higher IRR), the Project cannot be considered financially attractive.

Option III (benchmark analysis): if the project activity has a less favorable indicator, for example, a lower IRR than the reference, then the Project cannot be considered financially attractive.

If the investment analysis concludes that the Project is not financially attractive without the financial benefits derived from Verified Carbon Credits' sale, proceed to sub-step 2d (Sensitivity Analysis).

Sub-step 2d. Sensitivity analysis

Include a sensitivity analysis to assess whether the initial conclusion regarding the baseline scenario's financial attractiveness is robust to reasonable variations in the critical assumptions. The investment analysis only provides a valid argument in identifying the baseline scenario and demonstrating additionality if it consistently supports (for a realistic range of assumptions) the initial conclusion that the Project, without the financial benefits from the sale of VCC, is financially attractive.

If, after sensitivity analysis, the Project is unlikely to produce an economic benefit (Option I) or be financially attractive (Option II and Option III), then proceed directly to Step 4 (Impact of project registration).

If, after the sensitivity analysis, the Project is likely to produce economic benefits (Option I) or be financially attractive (Option II and Option III), then the Project cannot be considered additional using financial analysis. Optionally, continue with Step 3 (Barrier Analysis) to demonstrate that the proposed project activities face barriers preventing other probable land use alternatives.

STEP 3. Barrier analysis

The project holder may complete a barrier analysis as a separate additionality analysis or an investment analysis extension.

If this step is used, determine if the GHG project faces barriers that:

- (a) prevents or limits the implementation of this kind of GHG project; and,
- (b) do not prevent the implementation of at least one of the possible land-use alternatives.

Apply the following sub-steps:

Sub-step 3a. Identify the barriers that would prevent the project implementation

Identify real and credible barriers that prevent the Project's realization if it does not contemplate participation in the carbon market. The barriers should not be specific for the project participants but should apply to the project activity. Such barriers may include, among others:

Investment barriers, *inter alia*:

- Debt funding is not available for this type of Project;
- No private capital is available due to real or perceived risks associated with national or foreign direct investment in the country where the Project is to be implemented;
- Lack of access to credit;

Institutional barriers, *inter alia*:

- Risk related to changes in government policies or laws;
- Lack of enforcement of land-use-related legislation.

Technological barriers, *inter alia*:

- Lack of access to necessary materials, for example, planting materials;
- Lack of infrastructure for implementation of the technology;

Barriers related to local tradition, *inter alia*:

- Traditional knowledge or lack thereof, laws and customs, market conditions and practices;
- Traditional equipment and technology;

Barriers due to local ecological conditions, *inter alia*:

- Degraded soil (e.g., water or wind erosion, salination);
- Catastrophic natural or human-induced events (e.g., landslides, fire);
- Unfavorable meteorological conditions (e.g., early or late frost, drought);
- Invasive species that prevent the regeneration of trees (e.g., grasses, weeds);
- Lack of favorable ecological conditions for the growth of the crop;
- Presence of pests and diseases in a generalized pathway on the project area;
- Biotic pressure such as grazing or fodder collection.

Barriers due to social conditions, *inter alia*:

- Demographic pressure on the land (e.g., increased demand on land due to population growth);
- Social conflict among interest groups in the region where the Project takes place;
- Widespread illegal practices (e.g., illegal grazing, illicit crops, non-timber product extraction, and tree felling);
- Lack of skilled or adequately trained labor force;
- Public order situation;
- Lack of organization of local communities.

Barriers relating to land tenure, ownership, inheritance, and property rights, *inter alia*:

- Communal land ownership with a hierarchy of rights for different stakeholders that limits the incentives to undertake the land-use scenarios;
- Lack of suitable land tenure legislation and regulation to support the security of tenure;
- Absence of clearly defined and regulated property rights concerning natural resource products and services;
- Formal and informal tenure systems, increasing risks of land holdings' fragmentation.

Barriers relating to market, transportation, and storage, *inter alia*:

- Unregulated and informal markets for timber, non-timber products and services prevent the transmission of sufficient information to project participants;
- The remoteness of land area and undeveloped roads and infrastructure incur large transportation expenditures, thus eroding the competitiveness and profitability of products from the land use;
- Possibilities of considerable price risk due to the fluctuations in the prices of products over the project period in the absence of efficient markets and insurance mechanisms;
- The absence of facilities to convert, store and add value to products resulting from land-use limits the possibilities to capture rents from the land-use scenario.

The barriers identified constitute sufficient evidence to demonstrate the project additionality, only if they prevent the project's possible holders from carrying out the Project if their participation in the carbon market is not expected.

The GHG project holder shall provide transparent and documented evidence and offer conservative interpretations of how it demonstrates the identified barriers' existence and significance. The type of evidence to be provided may include:

- (a) Relevant legislation, regulatory information or environmental/natural resource management norms, acts, or rules;
- (b) Relevant (sectoral) studies or surveys (e.g., market surveys, technology studies) undertaken by universities, research institutions, associations, companies, bilateral/multilateral institutions, among others;
- (c) Relevant statistical data from national or international statistics;
- (d) Documentation of relevant market data (e.g., market prices, tariffs, rules);
- (e) Written documentation from the company or institution developing or implementing the Project, such as minutes from board meetings, correspondence, feasibility studies, financial or budgetary information;
- (f) Documents prepared by the project developer, contractors, or project partners in the context of the proposed project activity or similar previous project implementations;
- (g) Independent experts judgements' documentation. These experts come from agriculture, forestry, and other land-use related Government or Non-Government bodies or individual experts and educational institutions (e.g., universities, technical schools, training centres), professional associations, and others.

Sub-step 3 b. Demonstrate that the identified barriers would not prevent the implementation of at least one of the identified land use alternatives (except the project activity):

If the identified barriers also affect other identified alternatives, the project holder shall explain how the identified barriers do not prevent the implementation of at least one land-use alternatives. Any alternative prevented by barriers identified in Sub-step 3a is not a viable alternative and shall be removed from the analysis. At least one viable alternative, other than the Project, should be identified.

If one of Sub-steps 3a or 3b is not fulfilled, the Project cannot be considered additional through the barrier analysis.

If both Sub-steps (3a and 3b) are satisfied, proceed to Step 4 (Impact of project registration).

STEP 4. Impact of Project registration

Explain how certification and registration of the Project, and the associated benefits and incentives derived from this, would lessen the impact of economic and financial barriers (Step 2) or other identified barriers (Step 3) and enable the Project to proceed. The benefits and incentives can be of various types, such as:

- Net anthropogenic greenhouse gas removals by sinks;
- Revenue's financial benefit from the sale of VCCs, including its certainty and predefined timing;
- Attracting new stakeholders who are not exposed to the same barriers or can accept a lower IRR (e.g., because they have access to cheaper capital);
- Attracting new stakeholders that provide the ability to implement new technology or practice; and
- Reduction of inflation or exchange rate risk that affects expected revenues and is attractive to investors.

If Step 4 is met, the Project does not correspond to the baseline scenario and is therefore additional.

If Step 4 is not met, the Project is not additional.

12 Conservative selection of default values

According to the CDM Executive Board guidelines¹⁸, GHG project holders should ensure that the application of default data for the estimation of removals results in conservative (but not overly conservative).

When using default data to estimate the net anthropogenic GHG removals by sinks, the following guidance should be applied when selecting sources of data:

- If an approved A/R CDM methodology requires application of a default value and provides its numerical value then the value shall be considered as the conservative one;
- Values should if possible be species-specific, with selection from the following data sources (given in order of priority; highest first):
 - Local peer-reviewed studies under similar climate/soil conditionsóprovided the smaller datasets typical of local studies are considered sufficiently reliable; or
 - Regional or national forest or GHG inventory for the same ecological zone (that is, the same broad climate zone, and similar soil fertility and depth); or
 - International or global forest or GHG inventory, including IPCC literature, for the same ecological zone.
- If species-specific default data are not available, data may be selected from studies in the same ecological zone for the same genus 1 and regarded as conservative. Default data may also be selected from studies in the same ecological zone for the same family, provided the applicability of the data is checked (see Section 3.c. (i), in the AR Guideline). The priority for selection of default data sources should be that given in the bullet point above.

13 Stratification

If biomass distribution over the project area is not homogeneous, stratification should be carried out to improve biomass estimation precision. Different stratifications may be appropriate for the baseline and project scenarios to achieve optimal precision of estimation of net GHG removals by sinks. In particular:

- (a) For baseline net GHG removals by sinks, it is usually sufficient to stratify the project area according to land use categories;

¹⁸ https://cdm.unfccc.int/Reference/Guidclarif/ar/methAR_guid26.pdf

- (b) For the project scenario, stratification can be based on establishment plans (species/planting year).

14 Uncertainty management

Within the STANDARD BCR framework, uncertainty management is determined by a guide for applying discounts for quality and applicability of the data and parameters used to estimate GHG emissions' reduction or removal.

Implicitly, it is considered that the methodologies used in the quantification of GHG removals involve different degrees of uncertainty. They originate on the quality and applicability, either of the allometric equations for biomass estimation, or of the volume equations that, in conjunction with basic density values and expansion factors, are used to estimate individual trees' biomass.

It is also accepted that, given the nature of projects in the Agriculture, Forestry and Other Land Use sector and their biomass estimation methods, the methods, models, and data used should not generate overestimates.

Accordingly, this guide's purpose is for holders of GHG projects to consider, when choosing data for the estimation of GHG removals, discount factors related to uncertainty. These discounts should be applied according to the quality and origin of the estimation data applied.

In this case, the uncertainty does not correspond to the uncertainty related to the mean's value, defined in 3.6.a A/R Tool 14¹⁹.

Table 3 shows the estimated GHG reduction data and the discount factors associated with each of them.

Table 3. Quality discounts and applicability of GHG estimation models

Source of the estimation model and data/parameters	Discount factor (%)
Project-specific above-ground and below-ground biomass data, and density values of the project	0
Project-specific above-ground biomass data and (R:S) ⁽ⁱ⁾ for below-ground biomass factor	5
Regional above-ground and below-ground biomass data	10
Regional above-ground data ⁽ⁱⁱ⁾ and (R:S) factor for below-ground biomass	15

¹⁹ A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities. Version 04.1. En: <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v4.1.pdf>

Source of the estimation model and data/parameters	Discount factor (%)
National data for above-ground and below-ground biomass	15
National data for above-ground and y (R:S) factor for below-ground biomass	20
Above-ground and below-ground biomass data from other countries or regions with similar environmental conditions (climate-soils)	25
Above-ground biomass data and (R:S) factor for below-ground biomass from other countries or regions with similar environmental conditions (climate-soils)	30
Project-specific density values and factor (R:S) for below-ground biomass	15
IPCC density values and factor (R:S) for below-ground biomass	20
IPCC density and (R:S) factor for below-ground biomass	30
Volume equations from other countries or IPCC data, in areas with similar environmental conditions (climate-soils), IPCC density, and (R:S) factor for below-ground biomass	40
(i) The ratio between above-ground biomass and below-ground biomass (ii) Regional is the Project area where approximately the same climatic conditions are maintained	
reductions	

Meanwhile, if the data and parameters used for the calculation of GHG emission reductions are consistent with the emission factors, activity data, GHG emission projection variables, and other parameters used for the construction of the national GHG inventory and the national reference scenario, the application of the percentages defined for the discount factor is not necessary.

However, in those cases where the discounts listed in the Table (above) are not applied, uncertainty should be estimated according to section 6.1 or 6.2 of the CDM methodological tool for estimating carbon stocks in trees and shrubs²⁰, as described in the following paragraphs.

14.1 Difference of two independent stock estimations

Change in carbon stock in trees is estimated as the difference between two successive and independent carbon stock estimations.

This method is efficient when the correlation between the plot biomass values on the two occasions is absent or weak (e.g. when there has been harvest or disturbance in a stratum after the first estimation, resulting in spatial re-distribution of tree biomass in the stratum).

²⁰ Based on AR-TOOL14 Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities Version 04.2

Under this method, the change in carbon stock and the associated uncertainty are estimated as follows:

$$\Delta C_{TREE} = C_{TREE,t2} - C_{TREE,t1} \quad \text{Equation (1)}$$

$$\mu_{\Delta C} = \frac{\sqrt{(\mu_1 \times C_{TREE,t1})^2 + (\mu_2 \times C_{TREE,t2})^2}}{|\Delta C_{TREE}|} \quad \text{Equation (2)}$$

Where:

ΔC_{TREE} = Change in carbon stock in trees during the period between two points of time t_1 and t_2 ; t CO_{2e}

$C_{TREE,t1}$ = Carbon stock in trees as estimated at time t_1 ; t CO_{2e}
 Note 1. At the first verification $C_{TREE,t1}$ is set equal to the carbon stock in the pre-project tree biomass (i.e. $C_{TREE,t1} = C_{TREE,lb}$). However, this may be set equal to zero, if all of the conditions specified under paragraph 10 of the Tool are met.

Note 2. . Even if $C_{TREE,t1}$ was made conservative at the time of previous verification, it is the estimated (undiscounted) value of $C_{TREE,t1}$ that is used here.

$C_{TREE,t2}$ = Carbon stock in trees as estimated at time t_2 ; t CO_{2e}

$\mu_{\Delta C}$ = Uncertainty in ΔC_{TREE}

μ_1, μ_2 = Uncertainty in $C_{TREE,t1}$ y $C_{TREE,t2}$ respectively

14.2 Direct estimation of change by re-measurement of sample plots

This method is applicable only in ex-post estimation of change in carbon stock in trees for monitoring of project activities. Under this method, the same sample plots are measured on two successive occasions and the plot-level change in biomass is obtained by subtracting the plot biomass on the first occasion from the plot biomass on the second occasion.

This is method is efficient when there is a significant correlation between the plot biomass values on the two occasions (e.g. when there has been no harvest or disturbance in a stratum and therefore no significant spatial re-distribution of biomass has occurred in the stratum after the first estimation).

Under this method, the change in carbon stock and the associated uncertainty are estimated as follows:

$$\Delta C_{TREE} = \frac{44}{12} \times CF_{TREE} \times \Delta B_{TREE} \quad \text{Equation (3)}$$

$$\Delta B_{TREE} = A \times \Delta b_{TREE} \quad \text{Equation (4)}$$

$$\Delta b_{TREE} = \sum_{i=1}^M w_i \times \Delta b_{TREE,i} \quad \text{Equation (5)}$$

$$\mu_{\Delta C} = \frac{t_{VAL} \times \sqrt{\sum_{i=1}^M w_i^2 \times \frac{s_{\Delta,i}^2}{n_i}}}{|\Delta b_{TREE}|} \quad \text{Equation (6)}$$

Where:

ΔC_{TREE} = Change in carbon stock in trees between two successive measurements; t CO₂e

CF_{TREE} = Carbon fraction of tree biomass; t C (t d.m.)⁻¹

ΔB_{TREE} = A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.

Δb_{TREE} = Change in tree biomass within the biomass estimation strata; t d.m.

A = Sum of areas of the biomass estimation strata; ha

Δb_{TREE} = Mean change in tree biomass per hectare within the biomass estimation strata; t d.m. ha⁻¹

w_i = Ratio of the area of stratum i to the sum of areas of biomass estimation strata (i.e. $w_i = A_i/A$); dimensionless

$\Delta b_{TREE,i}$ = Mean change in carbon stock per hectare in tree biomass in stratum i ; t d.m. ha⁻¹

$\mu_{\Delta C}$ = Uncertainty in ΔC_{TREE}

t_{VAL} = Two-sided Student's t-value for a confidence level of 90 per cent and degrees of freedom equal to $n - M$, where n is total number of sample plots within the tree biomass estimation strata, and M is the total number of tree biomass estimation strata

$s_{\Delta,i}^2$	Variance of mean change in tree biomass per hectare in stratum i; (t d.m. ha ⁻¹) ²
n_i	Number of sample plots, in stratum i, in which tree biomass was re-measured

Under this method, the change in carbon stock and the associated uncertainty are estimated as follows:

$$\Delta b_{TREE,i} = \frac{\sum_{p=1}^{n_i} \Delta b_{TREE,p,i}}{n_i} \quad \text{Equation (7)}$$

$$s_{\Delta,i}^2 = \frac{n_i \times \sum_{p=1}^{n_i} \Delta b_{TREE,p,i}^2 - \left(\sum_{p=1}^{n_i} \Delta b_{TREE,p,i}\right)^2}{n_i \times (n_i - 1)} \quad \text{Equation (8)}$$

Where:

$\Delta b_{TREE,i}$	=	Mean change in carbon stock per hectare in tree biomass in stratum i; t d.m. ha ⁻¹
$\Delta b_{TREE,p,i}$		Change in tree biomass per hectare in plot p in stratum i; t d.m. ha ⁻¹
$s_{\Delta,i}^2$	=	Variance of mean change in tree biomass per hectare in stratum i; (t d.m. ha ⁻¹) ²
n_i	=	Number of sample plots, in stratum i, in which tree biomass was re-measured

For both of the above cases (sections 14.1 and 14.2), if $\mu_{\Delta C}$ is greater than 10 per cent, ΔC_{TREE} is made conservative by applying uncertainty discount according to the procedure provided in Table 4.

Table 4. Uncertainty discount factors

Uncertainty	Discount (% of μ)	How applied
$\mu \leq 10\%$	0%	Estimated mean = 60 ± 9 t d.m/ha i.e. $\mu = 9/60 \times 100 = 15\%$ Discount = $25\% \times 9 = 2,25$ t d.m/ha Discounted conservative mean:
$10 < \mu \leq 15$	25%	
$15 < \mu \leq 20$	50%	

Uncertainty	Discount (% of μ)	How applied
$20 < \mu \leq 30$	75%	In baseline= $60 \pm 2,25 = 62,25$ t d.m/ha In project= $60 - 2,25 = 57,75$ t d.m/ha
$\mu > 30$	100%	

15 GHG removals by sinks

15.1 Baseline net GHG removals by sinks

To consider GHG removals in the baseline scenario, the land cover in the project area (defined by the land use categories) should be considered.

According to what is established in the methodological tool to calculate changes in carbon stocks of trees and shrubs in afforestation and reforestation project activities, the baseline carbon stock in trees can be accounted as zero if all of the following conditions are met:

- (a) The pre-project trees are neither harvested, nor cleared, nor removed throughout the project horizon;
- (b) The pre-project trees do not suffer mortality because of competition from trees planted by the Project, or damage because of implementation of the project activity at any time during the project horizon;
- (c) The pre-project trees are not inventoried along with the project trees during carbon stocks monitoring.

If these conditions are not met, removals in the baseline scenario can be calculated as follows:

$$\Delta C_{BSL,t} = \Delta C_{TREE_BSL,t} + \Delta C_{SHRUB_BSL,t} + \Delta C_{DW_BSL,t} + \Delta C_{LI_BSL,t} \quad \text{Equation (9)}$$

Where:

- $\Delta C_{BSL,t}$ = Baseline net GHG removals by sinks in year t; t CO₂-e
- $\Delta C_{TREE_BSL,t}$ = Change in carbon stock in baseline tree biomass within the project boundary in year t, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO₂-e

$\Delta C_{SHRUB_BSL,t}$	Change in carbon stock in baseline shrub biomass within the project boundary, in year t, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO ₂ -e
$\Delta C_{DW_BSL,t}$	Change in carbon stock in baseline dead wood biomass within the project boundary, in year t, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks in deadwood and litter in A/R CDM project activities"; t CO ₂ -e
$\Delta C_{LI_BSL,t}$	Change in carbon stock in baseline litter biomass within the project boundary, in year t, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks in deadwood and litter in A/R CDM project activities"; t CO ₂ -e

15.2 Actual net GHG removals by sinks

GHG emissions resulting from the removal of herbaceous vegetation, combustion of fossil fuel, fertilizer application, use of wood, decomposition of litter and fine roots of N-fixing trees, construction of access roads within the project boundary, and transportation attributable to the project activities shall be considered insignificant and therefore accounted as zero.

Estimation of removals considers changes in carbon stocks in the project area, minus non-CO₂ GHG emissions at the project boundary resulting from project activities. GHG removals by sinks should be calculated as follows:

$$\Delta C_{ACTUAL,t} = \Delta C_t - GHG_{E,t} \quad \text{Equation (10)}$$

Where:

$\Delta C_{ACTUAL,t}$	=	Actual net GHG removals by sinks, in year t; t CO ₂ -e
ΔC_t	=	Change in the carbon stocks in Project, occurring in the selected carbon pools, in year t; t CO ₂ -e
$GHG_{E,t}$	=	Increase in non-CO ₂ GHG emissions within the project boundary as a result of the implementation of the A/R CDM project activity, in year t, as estimated in the tool "Estimation of non-CO ₂ GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity"; t CO ₂ -e

Change in the carbon stocks in Project, occurring in the selected carbon pools in year t shall be calculated as follows:

$$\Delta C_{P,t} = \Delta C_{TREE_PROJ,t} + \Delta C_{SHRUB_PROJ,t} + \Delta C_{DW_PROJ,t} + \Delta C_{LI_PROJ,t} + \Delta SOC_{A,t}$$

Equation (11)

Where:

$\Delta C_{P,t}$ = Change in the carbon stocks in Project, occurring in the selected carbon pools, in year t ; t CO₂-e

$\Delta C_{TREE_PROJ,t}$ = Change in carbon stock in tree biomass in Project in year t , as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO₂-e²¹

$\Delta C_{SHRUB_PROJ,t}$ = Change in carbon stock in shrub biomass in Project in year t , as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO₂-e

$\Delta C_{DW_PROJ,t}$ = Change in carbon stock in deadwood in Project in year t , as estimated in the tool "Estimation of carbon stocks and change in carbon stocks in deadwood and litter in A/R CDM project activities"; t CO₂-e

$\Delta C_{LI_PROJ,t}$ = Change in carbon stock in litter in Project in year t , as estimated in the tool "Estimation of carbon stocks and change in carbon stocks in deadwood and litter in A/R CDM project activities"; t CO₂-e

$\Delta SOC_{AL,t}$ = Change in carbon stock in SOC in Project, in year t , in areas of land meeting the applicability conditions of the tool "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities,"²² as estimated in the same tool; t CO₂-e

²¹ <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v4.2.pdf>

²² Methodological Tool "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities". <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-16-v1.1.o.pdf>

15.2.1 Trees and shrubs

Carbon stock in shrubs at a point of time is estimated on the basis of shrub crown cover. The area within the project boundary is stratified by shrub crown cover. Those areas where the shrub crown cover is less than 5 per cent are treated as a single stratum and the shrub biomass in this stratum is estimated as zero.

For the strata with a shrub crown cover of greater than 5 per cent, carbon stock in shrubs is estimated as follows:

$$C_{SHRUB,t} = \frac{44}{12} \times CF_s \times (1 + R_s) \times \sum_i A_{SHRUB,i} \times b_{SHRUB,i} \quad \text{Equation (12)}$$

$$b_{SHRUB,i} = BDR_{SF} \times b_{FOREST} \times CC_{SHRUB,i} \quad \text{Equation (13)}$$

Where:

$C_{SHRUB,t}$ = Carbon stock in shrubs within the project boundary at a given point of time in year t; t CO₂-e

CF_s = Carbon fraction of shrub biomass; t C (t.d.m.)⁻¹.

A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.

R_s = Root-shoot ratio for shrubs; dimensionless

The default value of 0.40 is used unless transparent and verifiable information can be provided to justify a different value.

$A_{SHRUB,i}$ = Area of shrub biomass estimation stratum i; ha

$b_{SHRUB,i}$ = Shrub biomass per hectare in shrub biomass estimation stratum i; t d.m. ha⁻¹

BDR_{SF} = Ratio of shrub biomass per hectare in land having a shrub crown cover of 1.0 (i.e. 100 per cent) and the default above-ground biomass content per hectare in forest in the region/country where the A/R CDM project activity is located; dimensionless.

A default value of 0.10 should be used unless transparent and verifiable information can be provided to justify a different value.

b_{FOREST} = Default above-ground biomass content in forest in the region/country where the A/R CDM project activity is located; t d.m. ha⁻¹.

Values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values.

$CC_{SHRUB,i}$ = Crown cover of shrubs in shrub biomass estimation stratum i at the time of estimation, expressed as a fraction (e.g. 10 per cent crown cover implies $CC_{SHRUB,i} = 0.10$); dimensionless

15.2.2 Deadwood and litter

The carbon in the deadwood and litter shall be estimated based on "AR TOOL 12 Estimation of carbon stocks and change in carbon stocks in dead Wood and litter in A/R CDM projects activities"²³.

This tool is based on the following assumptions:

- (a) The linearity of change of biomass in deadwood and litter over a time of period. Change of biomass in deadwood and litter may be assumed to proceed, on average, at an approximately constant rate between two points of time at which the biomass is estimated;
- (b) Appropriateness of root-shoot ratios: Root-shoot ratios appropriate for estimating below-ground biomass from above-ground biomass of living trees are also appropriate for dead trees.

The tool provides procedures to determine the parameters in Table 5.

Table 5. Parameters dead wood and litter

$C_{DW,i,t}$	Carbon stock in deadwood within the project boundary at a given point of time in year t; t CO ₂ e
$\Delta C_{DW,i,t}$	Change in carbon stock in deadwood within the project boundary in year t; t

²³ CDM-AR Tool 12 de la Metodología AR ACM0003. <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v3.1.pdf>

	CO ₂ e
$C_{LI,i,t}$	Carbon stock in litter within the project boundary at a given point of time in year t; t CO ₂ e
$\Delta C_{LI,i,t}$	Change in carbon stock in litter within the project boundary in year t; t CO ₂ e

Source: A/R Methodological Tool

Estimates of carbon stocks in deadwood are based on a conservative value, then, is possible to use a default-factor based method described in this section. For all strata to which the default-factor based method is applied, the carbon stock in deadwood is estimated as:

$$C_{DW,i,t} = C_{TREE,i,t} \times DF_{DW} \quad \text{Equation (14)}$$

Where:

$C_{DW,i,t}$ = Carbon stock in deadwood in stratum i at a given point of time in year t; t CO₂e

$C_{TREE,i,t}$ = Carbon stock in trees biomass in stratum i at a point of time in year t, as calculated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO₂e

DF_{DW} = Conservative default factor expressing carbon stock in deadwood as a percentage of carbon stock in tree biomass, percent

i = 1, 2, 3. ... biomass estimation strata within the project boundary

t = 1, 2, 3. ... years elapsed since the start of the project activity

In the case of not sampling based measurements for estimating C stock in the litter, it is necessary to use the default-factor-based method described below.

For all strata where the default method is applied, carbon stock in the litter is estimated as Equation 15:

$$C_{LI,i,t} = C_{TREE,i,t} \times DF_{LI} \quad \text{Equation (15)}$$

Where:

$C_{LI,i,t}$ = Carbon stock in litter in stratum i at a given point of time in year t ; t CO₂e

$C_{TREE,i,t}$ = Carbon stock in trees biomass in stratum i at a point of time in year t , as calculated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO₂e

DF_{LI} = Conservative default factor expressing carbon stock in the litter as a percentage of carbon stock in tree biomass

i = 1, 2, 3 ... biomass estimation strata within the project boundary

t = 1, 2, 3 ... years elapsed since the start of the project activity

The conservative values of the default factors, which express the carbon stocks in dead wood and litter, as a percentage of the carbon stock in tree biomass, are presented in Table 6 below.

Table 6. Default values used for dead wood and litter

Data / Parameter	CF _{LI}
Data unit	t C t ⁻¹ d.m
Description	Carbon fraction of litter biomass
Source of data	IPCC default value of 0.37 t C t ⁻¹ d.m. may be used
Data / Parameter	DF _{DW}
Data unit	Percentage

Description	Conservative default factor expressing carbon stock in deadwood as a percentage of carbon stock in tree biomass			
Source of data	Defaults conservatively derived from Delaney et al. 1997 ²⁴ , Smith et al. 2006 ²⁵ , Glenday 2008 ²⁶ , Keller et al. 2004 ²⁷ , Eaton and Lawrence 2006 ²⁸ , Krankina and Harmon 1995 ²⁹ , and Clark et al. 2002 ³⁰ :			
	Biome	Elevation	Precipitation	DF _{DW}
	Tropical	<2000m	<1000mm yr ⁻¹	2%
	Tropical	<2000m	1000-1600 mm yr ⁻¹	1%
	Tropical	<2000m	>1600 mm año ⁻¹	6%
	Tropical	>2000m	All	7%
	Temperate / Boreal	All	All	8%
Data / Parameter	DF _{LI}			
Data unit	Percentage			
Description	Default factor for the relationship between carbon stock in litter and carbon stock in living trees			
Source of data	Defaults conservatively derived from sources cited above:			
	Biome	Elevation	Precipitation	DF _{LI}
	Tropical	<2000m	<1000mm yr ⁻¹	4
	Tropical	<2000m	1000-1600 mm yr ⁻¹	1%
	Tropical	<2000m	>1600 mm yr ⁻¹	1%
	Tropical	>2000m	All	1%
	Temperate / Boreal	All	All	4%
Data / Parameter	R _j			
Data unit	Dimensionless			
Description	The root-shoot ratio for species j			

²⁴ Delaney, M., Brown, S., Lugo, A.E., Torres-Lezama, A. and Bello Quintero, N. 1997. The distribution of organic carbon in major components of forests located in five life zones of Venezuela. *Journal of Tropical Ecology* 13: 697-708.

²⁵ Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. Forest Service, Northeastern Research Station, General Technical Report NE-343. 216 p.

²⁶ Glenday, J. 2008. Carbon storage and emissions offset potential in an African dry forest, the ArabukoSokoke Forest, Kenya. *Environ. Monit. Assess* 142: 85-95

²⁷ Keller, M., Palace, M., Asner, G., Pereira Jr, R. and Silva, JNM. 2004. Coarse woody debris in undisturbed and logged forests in eastern Brazilian Amazon. *Global Change Biology* 10: 784-795.

²⁸ Eaton, J.M. and Lawrence, D. 2006. Woody debris stocks and fluxes during succession in a dry tropical forest. *Forest Ecology and Management* 232: 46-55.

²⁹ Krankina, O.N., Harmon, M.E., 1995. Dynamics of the dead wood carbon pool in northwestern Russian boreal forests. *Water Air Soil Pollut.* 82,227-238.

³⁰ Clark, D.B., Clark, D.A., Brown, S., Oberbauer, S.F., Veldkamp, E., 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. *Forest Ecol. Manage.* 5646, 1-112

Source of data	<p>Unless transparent and verifiable information can be provided to justify a different value, the value of R_j shall be calculated as:</p> $R_j = \frac{e^{(-1,085+0,9256*\ln b)}}{b}$ <p style="text-align: right;">Equation (16)</p> <p>R_j The root-shoot ratio for species j; dimensionless</p> <p>b Above-ground biomass per hectare (t d.m. ha⁻¹),</p> <p>j 1, 2, 3, ... specie</p> <p>Source: A/R Methodological Tool. "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities" and [Table 4.A.4 of IPCC GPG-LULUCF 2003]</p>
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Source: A/R Methodological Tool

15.2.3 Soil organic carbon (SOC)

The estimation of change in carbon stock in soil organic carbon (SOC) is calculated according to the "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities", version 1.1.0.

In addition, to quantify the organic carbon in the soil, the following shall be fulfilled:

- (a) Litter remains on-site and is not removed from the project area; and,
- (b) Soil disturbance attributable to the project activity, if any, is:
 - By appropriate soil conservation practices
 - Limited to site preparation before planting and is not repeated in less than twenty years;

It is assumed that implementing a project activity increases the lands' SOC content to a level that is equal to the steady-state SOC content under native vegetation. Also, the SOC content in the project scenario takes place at a constant rate over 20 years since the planting year.

The applicability conditions of the tool, to estimate the land change in SOC stock in the project scenario, are stratified according to:

- (a) Climate region and soil types in Table 7
- (b) Pre-project management activities on croplands in Tables 8 and 9; and
- (c) Pre-project management activities on grasslands (Table 10)

The initial SOC stock at the start of the Project is estimated as follows³¹:

$$SOC_{INITIAL,i} = SOC_{REF,i} \times f_{LU,i} \times f_{MG,i} \times f_{IN,i} \quad \text{Equation (17)}$$

Where:

$SOC_{INITIAL,i}$ = SOC stock at the beginning of the project activity in stratum i of the areas of land; t C ha⁻¹

$SOC_{REF,i}$ = Reference SOC stock corresponding to the reference condition in native lands (i.e., non-degraded, unimproved lands under native vegetation forest) by climate region and soil type applicable to stratum i of the areas of land; t C ha⁻¹

$f_{LU,i}$ = Relative stock change factor for baseline land-use in stratum i of the areas of land; dimensionless

$f_{MG,i}$ = Relative stock change factor for baseline management regime in stratum i of the areas of land; dimensionless

$f_{IN,i}$ = Relative stock change factor for baseline input regime (e.g., crop residue returns, manure) in stratum i of the areas of land; dimensionless

i = 1, 2, 3, strata of areas of land; dimensionless

The values of $SOC_{REF,i}$, $f_{LU,i}$, $f_{MG,i}$ y $f_{IN,i}$ are taken from Tables 5 - 8, unless transparent and verifiable information can justify different values.

For each stratum subjected to total area soil disturbance due to project activity, if disturbed area over and above in the baseline is greater than 10% of the area of the stratum, the following carbon loss is accounted as:

$$SOC_{LOSS,i} = SOC_{INITIAL,i} \times 0,1 \quad \text{Equation (18)}$$

Where:

³¹ Equation in CDM-AR Tool6

$SOC_{LOSS,i}$ = Loss of SOC caused by soil disturbance attributable to the project activity, in stratum i of the areas of land; t C ha⁻¹; t C ha⁻¹

$SOC_{INITIAL,i}$ = SOC stock at the beginning of the project activity in stratum i of the areas of land; t C ha⁻¹

0,1 = The approximate proportion of SOC lost within the first five years from the year of site preparation

i = 1, 2, 3, strata of areas of land; dimensionless

Table 7. Default reference SOC stocks (SOCREF) for mineral soils³²(tC ha⁻¹ in 0-30 cm depth)

Climate region	HAC ^(a) soils	LAC ^(b) soils	Sandy soils ^(c)	Spodic soils ^(d)	Volcanic soils ^(e)
Boreal	68	NA	10	117	20
Cold temperate, dry	50	33	34	NA	20
Cold temperate, moist	95	85	71	115	130
Warm temperate, dry	38	24	19	NA	70
Warm temperate, moist	88	63	3	NA	80
Tropical, dry	38	35	31	NA	50
Tropical, moist	65	47	39	NA	70
Tropical, wet	44	60	66	NA	130
Tropical montane	88	63	34	NA	80

(a) Soils with high activity clay (HAC) minerals are light to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols);

(b) Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols);

(c) Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psammments);

(d) Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols);

(e) Soils derived from volcanic ash with allophonic mineralogy (in WRB classification Andosols; in USDA classification Andisols)

Source: A/R Methodological Tool

In the project scenario, the rate of change in SOC stock until the steady-state SOC content reached is estimated as follows:³³

³² Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories

³³ CDM-AR Tool16. <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-16-v1.1.o.pdf>

$$dSOC_{t,i} = \frac{SOC_{REF,i} - (SOC_{INITIAL,i} - SOC_{LOSS,i})}{20 \text{ years}} \text{ for } t_{PREP,i} < t < t_{PREP,i} + 20$$

Equation (19)

Where:

$dSOC_{t,i}$ = The rate of change in SOC stock in stratum i of the areas of land, in year t ; $t \text{ C ha}^{-1} \text{ yr}^{-1}$

$SOC_{REF,i}$ = Reference SOC stock corresponding to the reference condition in native lands (i.e., non-degraded, unimproved lands under native vegetation forest) by climate region and soil type applicable to stratum i of the areas of land; $t \text{ C ha}^{-1}$

$SOC_{INITIAL,i}$ = SOC stock at the beginning of the A/R CDM project activity in stratum i of the areas of land; $t \text{ C ha}^{-1}$

$SOC_{LOSS,i}$ = Loss of SOC caused by soil disturbance attributable to the A/R CDM project activity, in stratum i of the areas of land; $t \text{ C ha}^{-1}$

$t_{PREP,i}$ = The year in which first soil disturbance takes place, in stratum i of the areas of land

i = 1, 2, 3, ... strata of areas of land; dimensionless

t = 1, 2, 3, ... years elapsed since the start of the project activity

The default factors for relative changes in carbon stocks for different management activities in crop areas are presented in Table 8.

Table 8. Default factors for relative changes in organic C stocks due to crop management activities (net effective over 20 years)

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
Land use, fLU	Long-term	Temperate/Boreal	Dry	0,80	The area has been

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
	cultivated		Moist	0,69	continuously managed for crops for more than 20 years
		Tropical	Dry	0,58	
			Moist/Wet	0,48	
		Tropical montane	n/a	0,64	
Land use, fLU	Short-term cultivated (< 20 yrs) or set aside (< 5 years)	Temperate/Boreal and Tropical	Dry	0,93	The area has been managed for crops for less than 20 years, or it is cropland in a fallow state for less than five years at any point during the last 20 years
			Moist	0,82	
		Tropical montane	n/a	0,88	
Management, fMG	Full tillage	All	Moist / Wet	1,00	Substantial soil disturbance with full inversion or frequent (within-year) tillage operations. At planting time, residues cover little of the surface (e.g., <30%)
Management, fMG	Reduced tillage	Temperate/Boreal	Dry	1,02	Primary or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Typically leaves the surface with >30% coverage by residues at planting
			Moist	1,08	
		Tropical	Dry	1,09	
			Moist / Wet	1,15	
		Tropical montane	n/a	1,09	

Source: A/R Methodological Tool

Table 9. Relative stock change factors for different levels of nutrient input on cropland (net effect over 20 years)

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
Input,	Low	Temperate/Boreal	Dry	0,95	There is residues removal (via

Factor type	Level	Temperature regime	Moisture regime	Factor value	Description and criteria
f_{IN}			Moist	0,92	collection or burning), or frequent bare-fallowing, or production of crops yielding low residues (e.g., vegetables, tobacco, cotton), or no mineral fertilization or N-fixing crops
		Tropical	Dry	0,95	
			Moist/Wet	0,92	
		Tropical montane	n/a	0,94	
	Medium	All	Moist/Wet	1,00	All crop residues are returned to the field. If residues are removed, then supplemental organic matter (e.g., manure) is added. Additionally, mineral fertilization or N-fixing crop rotation is practiced
	High without manure	Temperate/Boreal and Tropical	Dry	1,04	Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices, such as the production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied
			Moist/Wet	1,11	
		Tropical montane	n/a	1,08	

Source: A/R Methodological Tool

Table 10. Relative stock change factors (f_{LU} , f_{MG} , and f_{IN}) for grassland management (net effect over 20 years)

Factor type	Level	Climate regime	Factor	Description
Land use, f_{LU}	All	All	1,00	All permanent grassland is assigned a land-use factor of 1

Factor type	Level	Climate regime	Factor	Description
Management, f_{MG}	Non-degraded grassland	All	1,00	Non-degraded and sustainably managed grassland, but without significant management improvements
Management, f_{MG}	Moderately degraded grassland	Temperate / Boreal	0,95	Overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs
		Tropical	0,97	
		Tropical montane	0,96	
Management, f_{MG}	Severely degraded	All	0,70	Lands are identified as degraded lands using the "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities."
Input, f_{IN}	Low/Medium	All	1,00	All grassland without the input of fertilizers is assigned an input factor of 1
	High	All	1,11	Grasslands with direct application of fertilizers - organic or inorganic

Source: A/R Methodological Tool

Taking into account uncertainties and inherent precision limitation of a factor-based estimation by this tool, value of the rate of change of SOC stock is not accounted as more than 0.8 t C ha⁻¹ yr⁻¹, that is:

$$\text{If } dSOC_{t,i} > 0,8 \text{ t C ha}^{-1} \text{ yr}^{-1}, \text{ then } dSOC_{t,i} = 0,8 \text{ t C ha}^{-1} \text{ yr}^{-1}$$

SOC stock change for all strata of the areas of land, in year t, is calculated as:

$$\Delta SOC_{AL,t} = \frac{44}{12} \times \sum_i A_i \times dSOC_{t,i} \times 1\text{year} \quad \text{Equation (20)}$$

Where:

$\Delta SOC_{AL,t}$ = Change in SOC stock in areas of land meeting the applicability conditions of the A/R Tool16, in year t; t CO₂-e

A_i = The area of stratum i of the areas of land; ha

$dSOC_{t,i}$ = The rate of change in SOC stocks in stratum i of the areas of land; t C ha⁻¹ yr⁻¹

i = 1, 2, 3, ... strata of areas of land; dimensionless

15.3 Leakages

According to AR-ACM0003, for the leakage calculation, it is necessary to apply AR-TOOL15, *A/R Methodological Tool, Version 02.0* (Estimating the increase in GHG emissions attributable to the displacement of pre-project agricultural activities in A/R CDM project activity).

The tool is not applicable if the displacement of agricultural activities is likely to cause drainage directly or indirectly onto wetlands or peatlands.

Displacement of an agricultural activity by itself does not result in leakage emission. Leakage emission occurs when the displacement leads to an increase in GHG emissions relative to the GHG emissions attributable to the activity as it exists within the project boundary.

Leakage emission attributable to the displacement of grazing activities under the following conditions is considered insignificant and hence accounted as zero:

- (a) Animals are displaced to existing grazing land, and the total number of animals in the receiving grazing land (displaced and existing) does not exceed the carrying capacity of the grazing land;
- (b) Animals are displaced to existing non-grazing grassland, and the total number of animals displaced does not exceed the carrying capacity of the receiving grassland;
- (c) Animals are displaced to cropland that has been abandoned within the last five years;
- (d) Animals are displaced to forested lands, and no clearance of trees, or decrease in crown cover of trees and shrubs, occurs due to the displaced animals;

(e) Animals are displaced to a zero-grazing system.

In all other cases, the lands within the project boundary from which the pre-project agricultural activities are displaced shall be delineated and their area estimated. Leakage emission resulting from the activities displacement is estimated as follows:

$$LK_t = LK_{AGRIC,t} \quad \text{Equation (21)}$$

Where:

LK_t = Leakages t ; t CO₂-e

$LK_{AGRIC,t}$ = Leakage emission resulting from agricultural activities displacement in year t ; t CO₂-e

15.4 Net anthropogenic GHG removals by sinks

The net anthropogenic GHG removals by sinks shall be calculated as follows:

$$\Delta C_{PROJ,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t \quad \text{Equation (22)}$$

Where:

$\Delta C_{PROJ,t}$ = Net anthropogenic GHG removals by sinks, in year t ; t CO₂-e

$\Delta C_{ACTUAL,t}$ = Actual net GHG removals by sinks, in year t ; t CO₂-e

$\Delta C_{BSL,t}$ = Baseline net GHG removals by sinks, in year t ; t CO₂-e

LK_t = GHG emissions due to leakage, in year t ; t CO₂-e

16 Monitoring plan

The holders of GHG projects shall describe the procedures for monitoring project activities and reducing GHG emissions or removals within the Project's scope.

The monitoring plan shall provide for the collection of all relevant data necessary to:

- (a) Verify that the applicability conditions listed in number 5 of this document were met;

- (b) Verify changes in carbon stocks in selected pools;
- (c) Verify project emissions and leakages.

The data collected shall be archived for at least two years after the Project's last period. It shall include data and parameters monitored, processes related to models, methods used to generate data, sampling and quality control thereof, and appropriate collection and archiving.

The monitoring plan shall include:

- (a) Monitoring of Project boundaries;
- (b) Monitoring of the execution of activities for crops (forest or palm oil);
- (c) Monitoring of crop management and growth in biomass for crops (forestry and palm oil) and;
- (d) Monitoring the quantification of net anthropogenic GHG removals by sinks.

The information related to the data needed for carbon estimates should be established using commonly accepted principles and practices to manage forest systems and oil palm crops.

16.1 Monitoring of the project boundaries

The geographical limits of the Project, consisting of the eligible areas³⁴ on which the project activities are developed (forestry or palm oil crops), shall be included in a Geographic Information System (GIS), georeferencing each of the planted areas with their respective ID, coverage at the reference dates for each of the areas in each of the crops, among others.

In this way, monitoring of project activities is carried out for each of the geographic areas included in the Project. Periodic verification of the project boundaries should be carried out by evaluating satellite images, consistent with the eligibility analysis of the areas in the Project.

16.2 Monitoring of the implementation of project activities

Following practices in the Agriculture, Forestry, and other land-use sectors, the monitoring activities for the implementation of project activities shall be as follows:

- (a) Confirm that soil preparation and site selection are carried out as described in the establishment and management plans and the project document;

³⁴ Eligible areas refers to the areas that comply with the condition of absence of forest or natural covers, on the reference dates established by the BCR STANDARD.

- (b) Annually review and update planted areas by species and strata;
- (c) Determine plantations survival, and biomass decreases in the areas or events that determine them.

Table 11. Variables to monitor sites establishment

Variable	Unit of measurement	Measured (m), calculated (c) estimated (e) or default (d)	Recording frequency	Coverage / Other measurements or number of data collected	Observations
ID - Ref.GIS	alphanumeric	Defined	Continuously	100%	Each stratum and crop established, associated with an alphanumeric identifier.
Localization	geographic coordinates	m	Continuously	100%	Using GPS to identify the geographic coordinates of each lot included in the Project.
A _{ikt}	hectare	c	Continuously	100%	Polygons of the areas planted during time t, by stratum i, by model k (by species or date).
Site preparation	hectare	M	At the beginning of each establishment	100% of the planted areas	Intervened area for crop establishment.
Planted species for each stratum	NA	Defined	Annually	100%	Species planted by each stratum within the project boundaries.
Survival of i, j, k.	Trees ha ⁻¹	m, c	Three months after planting and annual verification	100% of the planted area	The survival rate per hectare established, for stratum i, species j, and forest system k is calculated.
Planting date	alphanumeric	m	Start date of each establishment	100%	Date of the planting of each project site.

Source: BioCarbon Registry, 2022

16.3 Site management and biomass growth monitoring

The following monitoring activities related to site management shall proceed to guarantee the quality of the planted areas and confirm that the activities were implemented following the descriptions presented in the project document:

- (a) Assessment of permanence and growing of the planted areas within the Project boundaries, by measuring growth plots.
- (b) Identification and evaluation of disturbance events caused in planted areas. This data includes, e.g., the date, location, coordinates, species(s) affected, type of event (such as fire, pests, windthrow, flooding), corrective measures implemented, changes in project boundaries, and the type of disturbance.

The holder of the mitigation project shall establish a Protocol to measure growth plots, as described below.

16.3.1 Stratification and sampling design

16.3.1.1 Stratification

As established in section 13 of this document, the defined strata should be evaluated and under appropriate statistical methodological procedures.

16.3.1.2 Sampling plots

Temporary sampling plots are required, which depends on the number of strata present in the project boundaries. These plots allow for monitoring changes in above-ground biomass. All plots shall be adequately numbered, georeferenced, and located within a map of areas established within the project boundaries.

NOTE: If permanent plots are available in the project area, they can be used for sampling. However, it is considered good practice to establish temporary plots.

16.3.1.3 Size of plots or sampling units

It is recommended to establish a plot size according to individuals' density in the plantation or crop. In general, circular plots can be used, with an area of 250 or 400 m².

16.3.1.4 Sampling size

In order to obtain the information required³⁵ for calculating the number of plots needed for monitoring, preliminary sampling should be carried out. The number of plots for preliminary sampling is defined by the number of strata and the selected sampling intensity.

The sample size (n) is estimated with the following equation:

$$n = \frac{A_i \times 10.000 \times \text{Sampling intensity}^{36}}{PS} \quad \text{Equation (23)}$$

³⁵The approximate value of the variance of the biomass reserves, in each stratum and/or lot.

Where:

n Number of plots required for biomass estimation; dimensionless

A_i Size of each stratum i ; ha

PS Plot size (constant for all strata); ha.

To calculate the number of sampling plots, the CDM Methodological Tool: A/R Methodological Tool is used. "Calculation of the number of sample plots for measurements within A/R CDM Project activities."³⁷ The scope, assumptions, parameters, and procedure for the calculation, defined in the tool, are detailed next.

Scope

- (a) The tool can be used to calculate the number of sample plots required for estimation of biomass stocks from sampling-based measurements in the baseline and project scenarios.
- (b) The tool calculates the number of required sample plots based on the specified targeted precision for biomass stocks to be estimated.
- (c) For this tool's purpose, all parameters used in calculating plot-level biomass stock (e.g., biomass expansion factors, root-shoot ratios) are considered fixed constants. Similarly, all models used to calculate plot-level biomass stock (e.g., volume tables or equations, allometric equations) are considered to be exact.

Assumptions

- (a) The approximate area value of each stratum within the project boundary is known;
- (b) The approximate variance of biomass stocks value in each stratum is known from a preliminary sample, existing data related to the project area, or existing data related to a similar area.
- (c) The project area is stratified into one or more strata.

Parameters

³⁶ The project holder shall select the sampling intensity, depending on the planted areas (it can be 0.5% or 0.1%, in relation to the size of the planted area).

³⁷ <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.o.pdf>

The tool provides the steps to estimate the following parameters:

Table 12. Parameters determined by the tool for sampling

Parameter	Unit	Description
n	Dimensionless	Number of sample plots required for estimation of biomass stocks within the project boundary
n_i	Dimensionless	Number of sample plots allocated to stratum i for estimation of biomass stocks within the project boundary

Source: A/R CDM methodological tool

16.3.1.5 Calculation of sample plots number

The required sample plots number for the estimation of biomass stocks in a carbon reservoir depends on the targeted precision and the variability of the estimated biomass stock. Targeted precision is specified by the Methodology applying the tool.

The project area is stratified based on the variability of estimated biomass stock and area of each stratum. If the biomass stock being estimated is the sum of biomass stocks in two or more pools, then stratification is carried out on the basis of the variability of the dominant reservoir (i.e., the reservoir containing the most considerable amount of biomass stock).

For the tool, biomass stock variability is expressed as the standard deviation of biomass stock in the stratum. The approximate value of the standard deviation of biomass stock in each stratum at the time of estimation is either known from existing data applicable to the project area or existing data related to a similar area or estimated based on a preliminary sample and expert judgment.

The number of sample plots required for estimating biomass stocks within the project boundary is calculated iteratively. In the first iteration, it is calculated as:

$$n = \frac{N * t_{VAL}^2 * (\sum_i w_i * s_i)^2}{N * E^2 + t_{VAL}^2 * \sum_i w_i * s_i^2} \quad \text{Equation (24)}$$

Where:

n Number of sample plots required for estimation of biomass stocks within the project boundary; dimensionless

N Total number of possible sample plots within the project boundary (i.e., the

sampling space or the population); dimensionless

t_{VAL}	Two-sided Student's t-value, at infinite degrees of freedom, for the required confidence level; dimensionless
w_i	The relative weight of the area of stratum i (i.e., the area of the stratum i divided by the project area); dimensionless
s_i	The estimated standard deviation of biomass stock in stratum i; t d.m. (or t d.m. ha ⁻¹)
E	Acceptable margin of error (i.e. one-half the confidence interval) in the estimation of biomass stock within the project boundary; t d.m. (or t d.m. ha ⁻¹), i.e., in the units used for S_i
i	1,2, 3, ... biomass stock estimation strata within the project boundary

16.3.1.6 Allocation of sample plots

The establishment of the sampling units is done randomly or systematically. In random sampling, with randomly selected points, the plot centre's subjective location (plot center, plot reference points, or movement of the plot center to a more "convenient" position) should be avoided, following the principle of randomness.

GPS should be used for their location and georeferencing in the field, thus allowing easy access and location. The sampling plots shall be identified with alphanumeric code series, and the information of their geographic position (GPS geographic coordinates), the location of the sampling unit, and the strata shall be recorded and archived.

16.3.1.7 Monitoring frequency

The GHG project holder shall establish a monitoring frequency according to the needs of verification and certification.

16.3.1.8 Measuring and estimating changes in carbon contents

The increase in above-ground biomass is measured. Therefore, each tree's individual growth or palm oil shall be monitored in the sampling plots. Changes in carbon content in other components of the above-ground (branches and leaves) and below-ground (roots) biomass of individuals in each plot shall be estimated by expansion factors or by adjusting allometric biomass equations, if available for the species.

16.4 Monitoring of the quantification of project removals

The estimate of actual removals considers the changes in carbon stocks in the project area, minus the estimate of non-CO₂ GHG emissions at the project boundaries resulting from the implementation of project activities.

According to the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities,"³⁸ the change in carbon stocks in trees is estimated using the following steps:

- (a) Use appropriate equations to estimate tree carbon stocks (in living, above-ground, and below-ground biomass). Using expansion factors - Biomass Expansion Factor (BEF), or specific biomass allometric equations that do not require expansion factors.
- (b) Use appropriate equations to estimate carbon stocks in trees. Using volume tables or equations used to convert wood volume (in forestry activities) from stem to above-ground biomass, or using expansion factor that relates root biomass to total above-ground biomass.

In this way, the biomass of trees of species *j* can be estimated as:

$$B_{TREE,j,i,t} = V_{TREE,j,i,t} \times D_j \times FEB_j \times (1 + R_j) \quad \text{Equation (25)}$$

Where:

$B_{TREE,j,i,t}$	Biomass of trees of species <i>j</i> in sample plot <i>p</i> of stratum <i>i</i> at a point of time in year <i>t</i> ; t d.m
$V_{TREE,j,i,t}$	Stem volume of trees of species <i>j</i> in sample plot <i>p</i> of stratum <i>i</i> at a point of time in year <i>t</i> , estimated by using the tree dimension(s) as entering data into a volume table or volume equation; m ³
D_j	Basic wood density of tree species <i>j</i> ; t d,m; m ⁻³
BEF_j	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass, for tree species <i>j</i> ; dimensionless
R_j	The root-shoot ratio for tree species <i>j</i> ; dimensionless
<i>j</i>	Tree species

³⁸ <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.o.pdf>

The biomass $B_{TREE,j,p,i,t}$, maybe estimated for species and stratum using the annual volume per hectare. The annual volumes for each species are taken from the data resulting from the inventories at the date of monitoring.

In the case of palm oil crops, biomass equations can be used to represent site conditions.

According to annex 24, EB 67 (A/R Methodological Tool "Demonstrating appropriateness of volume equations for estimation of above-ground tree biomass in A/R CDM project activities")³⁹ *"A species-specific or group-of-species-specific volume table or volume equation derived from trees growing in edapho-climatic conditions similar to those in the project area is considered appropriate, and hence can be used for ex-post estimation of tree stem volume"*⁴⁰. In all cases, the data used shall meet this condition.

The holder of the GHG project shall include the sources of the equations used. For example, published volume or biomass equations that are reasonably applicable to the species and site, or equations developed by the proponent for which the proponent can demonstrate their origin and applicability. Besides, the QA/QC process should consider verifying the validity of the equations.

Finally, with the field measurements results, the carbon stocks (total of tons of CO_{2e} at the date of the inventory) are calculated in the carbon pools included in the Project, according to the Methodology applied (AR-ACM0003).

16.5 Quality control and quality assurance procedures

The GHG project holder shall design a quality management and assurance system to ensure the proper management, quality, and reliability of the information. The Quality Control/Assurance Control (QA/QC) system should conform to IPCC recommendations. To provide consistency in the processes, protocols, and manuals should be developed for all project activities. The QA/QC process, including what is described in the following sections.

16.5.1 Field data verification

This activity consists of monitoring and evaluating the data recorded on the field forms. The purpose is to identify the accuracy and consistency of the sampling data. It also verifies that the required percentage of error is met (10%)⁴¹. General aspects of evaluation and follow-up:

- (a) The plots' re-measurements shall select random points covering between 10 and 20% of the total plots established in the initial sampling. The re-measurements shall not

³⁹ <https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-18-v1.0.1.pdf>

⁴⁰ if at least one of the 3 conditions is satisfied

⁴¹ In case of non-compliance, new field measurements shall be carried out.

show deviations greater than 5% compared to the initial ones. Any errors found shall be corrected and reported;

- (b) Carry out the measurements with instruments of similar characteristics to those used in the initial sampling;
- (c) Follow the same technical protocols for the plots establishment and the measurement of the variables;
- (d) Comparison of the information obtained during the follow-up measurement, with the initial sampling and identification of errors and omissions.

If errors are identified, they shall be corrected and documented, expressed as a percentage of the total measurements. The permissible error figure shall be 5%; if the error is greater, a new sampling shall include all the plots.

16.5.2 Review of information processing

The processing of the data collected in the field and the digital systems recording shall be reviewed. It shall use a sample of 10% of the records (selected at random), to identify possible inconsistencies. If there are errors, a percentage estimate of the errors should be made. The typing error should not exceed 10%; in this case, the total data should be reviewed and the necessary corrections made.

16.5.3 Data recording and storage system

The information should be stored in an organized and secure manner in digital and physical formats with sufficient copies (depending on the personnel in charge). In general, each file should contain field forms, estimates of carbon content changes (equations and calculations), geographic information (GIS), and measurement and monitoring reports.

According to the Methodology, the data collected shall be archived for at least two years after the project activity's last accreditation period.

Document history

Version	Date	Type of document	Nature of the review
1.0	December 10, 2019	Methodological Document sectoral GHG projects in the AFOLU sector	Initial version – Document submitted to public consultation
2.0	March 27, 2020	Methodological Document sectoral GHG projects in the AFOLU sector	Updated version – After public consultation
2.1	August 27, 2020	Methodological Document sectoral GHG projects in the AFOLU sector	Adjusted version Minor editorial changes
2.2	October 19, 2020	Methodological Document sectoral GHG projects in the AFOLU sector	Updated version Adjustments in the section Uncertainty Management
2.3	November 25, 2021	Quantification of GHG Emission Reductions from GHG projects. GHG REMOVAL ACTIVITIES.	Updated version Change of title to specify that it does not apply only to sectoral GHG projects. Clarifications on eligible projects. Definition of GHG projects. Adjustments to the applicability conditions. Adjustments in section 6. Normative references
3.0	April 13, 2022	Quantification of GHG Emission Reductions. GHG Removal Activities	Updated version Adjustment of scope and normative references Adjustment of additionality analysis. Updated uncertainty analysis. Estimation of carbon stocks in trees and shrubs.