PLAN VIVO

## PV Climate Module

# PU001

## Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects

*Version 1.1*

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PLAN VIVO

# Contents

# 1 Summary

This module is part of the Plan Vivo Agriculture and Forestry Carbon Benefit Assessment Methodologies (**PM001**). It is applicable to project interventions that result in net-removal of GHGs from the atmosphere, including afforestation and reforestation, forest restoration, agroforestry and farm forestry, and changes to cultivation practices. It can be used to provide values for the following parameters:

Baseline removals in eligible carbon pools:

$BR_{WB,a,y}$ Net GHG removals in woody biomass under the baseline scenario for project area *a* up to year *y* (see Section 5.1.2)

$BR_{WB\_LTA,a,y}$ Long-term average net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.7)

$BR_{NB,a,y}$ Net GHG removals in aboveground non-woody biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.2.2)

$BR_{BG,a,y}$ Net GHG removals in belowground biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.3)

$BR_{DW,a,y}$ Net GHG removals in dead wood under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.4.1)

$BR_{LI,a,y}$ Net GHG removals in litter under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.4.1)

$BR_{SO,a,y}$ Net GHG removals in soil organic carbon under the baseline scenario for project area *a* up to year *y* 5.4.1(t $CO_2e$; see Section 5.5.1)

$BR_{WP,a,y}$ Net GHG removals in wood products under the baseline scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.6)

Project removals in eligible carbon pools:

$PR_{WB,a,y}$ Net GHG removals in aboveground woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.1.3)

$PR_{WB\_LTA,a,y}$ Long-term average net GHG removals in aboveground woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.7)

$PR_{NB,a,y}$ Net GHG removals in aboveground non-woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.2.2)

$PR_{BG,a,y}$ Net GHG removals in belowground biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.3)

$PR_{DW,a,y}$ Net GHG removals in dead wood under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.4.2)

$PR_{LI,a,y}$ Net GHG removals in litter under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.4.2)

$PR_{SO,a,y}$ Net GHG removals in soil organic carbon under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.5.2)

$PR_{WP,a,y}$ Net GHG removals in wood products under the project scenario for project area *a* up to year *y* (t $CO_2e$; see Section 5.6)

Procedures for estimating baseline and project removals from the different carbon pools include direct measures, modelling and default factors.

# 2 Sources

This module includes procedures from the following CDM Methodologies and Tools:

**AR-ACM0003** A/R Large-scale Consolidated Methodology: Afforestation and reforestation of lands except wetlands, Version 2.0

**AR-AM0014** Afforestation and reforestation of degraded mangrove habitats, Version 3.0

**AR-AMS003** Afforestation and reforestation project activities implemented on wetlands, Version 3.0**AR-TOOL12** Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities, Version 3.1

**AR-TOOL14** Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities, Version 4.2

**AR-TOOL16** Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities, Version 1.1

This module applies the following Plan Vivo Tools:

**PT001** Smallholder Agriculture Monitoring and Baseline Assessment (SHAMBA) Tool, Version 2.0

**PT003** Guidance for the Use of Models Validated with Measurements in PV Climate Projects, Version 1.0

**PT004** Identification of Degraded and Degrading Land in PV Climate Projects, Version 1.0

This module references the following IPCC Guidance:

**IPCC 2019** Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Published by the Published by the Intergovernmental Panel on Climate Change. ISBN 978-4-88788-232-4.

# 3 Definitions

Definitions used in this module follow the latest version of the Plan Vivo Glossary, **PM001** and the following.

**Organic soils**

Soils are organic if they satisfy the requirements 1 and 2, or 1 and 3 below (FAO, 1998):

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

# 4 Applicability Conditions

This module is applicable to Plan Vivo project interventions that result in net-removal of GHGs from the atmosphere. This includes any of the following intervention types:

Agroforestry and farm forestry;
Changes to cultivation practices;
Changes to livestock management;
Afforestation and reforestation; and
Forest restoration.

This module can be used for:

- Estimation of net GHG removals by carbon pools in the baseline scenario,
- Estimation of expected net GHG removals by carbon pools in the project scenario, and

- Estimation of net GHG removals by carbon pools achieved in the project scenario

This module is applicable if all of the following conditions are met:

a. Soil disturbance[1] attributable to the project activity does not cover more than 10 per cent of the area[2] in each of the following types of land, when these lands are included within the project boundary:
    i. Land containing organic soils;
    ii. Land which, in the baseline scenario, is subjected to land-use and management practices and receives inputs listed in appendices 1 and 2 of CDM Methodology **AR-ACM003** v2.0;
    iii. Wetlands.
b. The project activity does not lead to alteration of hydrology of the project area or hydrologically connected wetland areas, unless this results from restoration of degraded wetlands by planting native species.

Projects applying this module shall also comply with the applicability conditions of any tools applied.

# 5 Procedures

## 5.1 Woody biomass

### 5.1.1 Stratification

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

a. For baseline net GHG removals, it is usually sufficient to stratify the area according to major vegetation types and their crown cover and/or land use types;
b. For actual net GHG removals the stratification for estimations should consider the project planting/management plan and the stratification for measurements should be based on the actual implementation of the project planting/management plan. If natural or anthropogenic impacts (e.g. local fires) or other factors (e.g. soil type) significantly alter

[1] Soil disturbance refers to any activity that results in a decrease in soil organic carbon (SOC), for example ploughing, ripping, scarification, digging of pits and trenches, stump removal, etc.

[2] For example, digging pits of size 0.50 m × 0.50 m (length × width) at a spacing of 3 m × 3 m is equal to a coverage of 2.78 per cent; continuous ploughing of land is equal to a coverage of 100 per cent.

the pattern of biomass distribution in the project area, then the stratification should be altered to reflect this.

### 5.1.2 Baseline removals in woody biomass

Baseline removals in woody biomass can be estimated with any of the following approaches:

i. Measurements in matched control areas, following the procedures in **AR-TOOL14** v4.2. The matching criteria to determine appropriate control areas are described in Table 1.
ii. Modelling of tree growth and stand development, following the guidance in **PT003**; or
iii. Assuming no change in woody biomass carbon stocks if the conditions in **AR-TOOL14** v4.2 Section 5 paragraph 12, or **PT004** are met.

*Table 1 Matching Criteria*

| Factor | Criteria |
|---|---|
| Location | Control areas must be within 100 km of the project area(s) they are matched with; and must be within the same jurisdictional boundary as the project area. Jurisdictional boundaries are either national boundaries, or if there is a government defined sub-national jurisdictional boundary defined for REDD+ reporting, the sub-national jurisdictional boundary must be used.<br>Control areas may exclude any areas that overlap existing projects registered under a carbon offset programme with activities that could affect the carbon pools accounted for by the project. |
| Vegetation type | At the start of the quantification period, control areas must have a similar vegetation type to the matched project area. Tree cover and/or above-ground woody biomass should not be more than 5% lower or more than 15% higher than in the matched project area, [3] and all control areas must be in the same ecoregion (Olson et al. |

[3] This similarity threshold aims to minimise to minimise the chance that biomass increase in the control plots is lower than the without-project scenario for the project area, while providing some flexibility in selecting control areas. The threshold is asymmetrical because control plots with biomass lower than the project areas they are matched with are likely to accumulate biomass more slowly than the project areas. For example, a project area with biomass of 50 tC/ha could be matched with a control area with biomass between 47.5 and 57.5 tC/ha.

| | |
|---|---|
| | 2012)[4] and land cover class (Brown et al. 2022)[5] as the plots they are matched with. |
| Policy environment | If there are any sub-national government-funded programmes being implemented that provide incentives for activities that are likely to affect the carbon pools accounted for by the project (such as tree planting or land restoration), control areas must have the same eligibility for such programmes as the areas they are matched with i.e. if the project area is eligible for the programme the control area must also be eligible, and if the project area is not eligible for the programme the control area must also be ineligible. Note that the requirement is based on eligibility to join the programme and not participation in the programme. |
| Land use | Control areas must have the same land use as the baseline scenario for the project area(s) they are matched with. |
| Land management | Control areas must be subject to the same land management practices as the baseline scenario for the project area(s) they are matched with. |
| Land tenure | Control areas must have the same land tenure classification as the project area(s) they are matched with. As a minimum land tenure classification should distinguish between public, private and community ownership, and where possible more precise classifications should be used. |

If using the procedures in **AR-TOOL14** v4.2, baseline removals in woody biomass are calculated with Equation 1. If the baseline scenario includes harvesting of trees, approaches for defining long-term average baseline removals in tree biomass described in Section 5.7 must be followed.

[4] Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938. https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

[5] Brown, C.F., Brumby, S.P., Guzder-Williams, B. *et al.* Dynamic World, Near real-time global 10 m land use land cover mapping. *Sci Data* **9**, 251 (2022). https://doi.org/10.1038/s41597-022-01307-4

**Calculation of baseline removals in woody biomass**

$$BR_{WB,a,y} = \sum_{t=1}^{y} \Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t}$$

*Equation 1*

Where:

$BR_{WB,a,y}$ Net GHG removals in aboveground and belowground woody biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{TREE\_BSL,t}$ Change in carbon stock in tree biomass under the baseline scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL14** v4.2, excluding uncertainty adjustment)

$\Delta C_{SHRUB\_BSL,t}$ Change in carbon stock in shrub biomass under the baseline scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL14** v4.2, excluding uncertainty adjustment)

### 5.1.3 Project removals in woody biomass

*Expected project removals in woody biomass*

Expected project removals in woody biomass can be estimated with the following approach:

i. Modelling of tree/shrub growth and stand development, following the guidance in **PT003** and **AR-TOOL14** v4.2 Section 8.2.

If the project scenario includes harvesting of trees, approaches for defining long-term average project removals in woody biomass described in Section 5.7 must be followed.

*Actual project removals in woody biomass*

Actual removals in woody biomass achieved by the project can be estimated with either of the following approaches:

i. Measurements within the project area following the procedures in **AR-TOOL14** v4.2 Sections 6 to 8 for trees and Sections 9 to 11 for shrubs, or
ii. Modelling of tree growth and stand development, following the procedures in **PT003**.

If using the measurement procedures in **AR-TOOL14** v4.2, project removals in woody biomass are calculated with Equation 2. If the project scenario includes harvesting of trees, approaches for defining long-term average project removals in woody biomass described in Section 5.7 must be followed.

**Calculation of project removals in woody biomass**

$$PR_{WB,a,y} = \sum_{t=1}^{y} \Delta C_{TREE\_PROJ,t} + \Delta C_{SHRUB\_PROJ,t}$$

*Equation 2*

Where:

$PR_{WB,a,y}$ Net GHG removals in aboveground and belowground woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{TREE\_PROJ,t}$ Change in carbon stock in tree biomass under the project scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL14** v4.2 excluding uncertainty adjustment)

$\Delta C_{SHRUB\_PROJ,t}$ Change in carbon stock in shrub biomass under the project scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL14** v4.2,).

## 5.2 Non-woody biomass

Removals in non-woody biomass in the baseline and project scenario can be calculated with Equation 3 and Equation 4.

**Calculation of baseline and project removals in non-woody biomass**

$$BR/PR_{NB,a,y} = \sum_{t=1}^{y} \Delta C_{HERB,a,t}$$

*Equation 3*

Where:

$BR/PR_{NB,a,y}$ Net GHG removals in non-woody biomass under the baseline or project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{HERB,a,t}$ Removals in non-woody biomass in project area *a* in year *t* (t $CO_2e$; see Equation 4)

**Calculation of annual removals in non-woody biomass**

$$\Delta C_{HERB,a,t} = A_{HERB,t} \cdot B_{HERB,t} - A_{HERB,t-1} \cdot B_{HERB,t-1}$$

*Equation 4*

Where:

$\Delta C_{HERB,a,t}$ Removals in herbaceous vegetation in project area *a* in year *t* (t $CO_2e$)

$A_{HERB,t}$ Area of herbaceous vegetation in project area *a* in year *t* (ha)

| | |
|---|---|
| $B_{HERB,t}$ | Above-ground biomass of herbaceous vegetation in year t (t $CO_2$e/ha) |
| $A_{HERB,t-1}$ | Area of herbaceous vegetation in project area *a* in year *t-1* (ha) |
| $B_{HERB,t-1}$ | Above-ground biomass of herbaceous vegetation in year *t*-1 (t $CO_2$e/ha) |

### 5.2.1 Baseline removals in non-woody biomass

Baseline removals in non-woody biomass can be estimated with any of the following approaches:

i. Modelling of vegetation growth, following the guidance in **PT003**, or applying clearly conservative growth estimates;
ii. Measurements in matched control areas, following the matching criteria to determine appropriate control areas described in Table 1, and using Equation 3 and Equation 4; or
iii. Assuming no change in non-woody biomass carbon stocks if the conditions in **PT004** are met.

### 5.2.2 Project removals in non-woody biomass

*Expected project removals in non-woody biomass*

Expected project removals in non-woody biomass can be estimated with the following approach:

i. Modelling of vegetation growth, following the procedures in **PT003**, or applying clearly conservative growth estimates.

*Actual project removals in non-woody biomass*

Actual removals in non-woody biomass achieved by the project can be estimated with either of the following approaches:

i. Measurements within the project area and using Equation 3 and Equation 4, or
ii. Modelling of vegetation growth following the procedures in **PT003**

## 5.3 Belowground biomass

Belowground biomass is estimated by applying an appropriate root:shoot ratio or allometric equation to estimates of aboveground biomass. Baseline and project removals in belowground biomass can then be estimated following the approaches in Section 5.1 (for woody biomass) or 5.2 (for non-woody biomass).

Baseline and project removals in belowground biomass are estimated by applying an appropriate root:shoot ratio or allometric equation to estimates of removals in aboveground biomass. Depending on the procedures used, the root:shoot ratio or allometric models can be applied at an individual tree or plant level, or stand/biome level.

Equation 5 should be used if applying a root:shoot ratio.

**Calculation of belowground biomass**

$$B_{BG} = B_{AG} \cdot R$$

*Equation 5*

Where:

$B_{BG}$ Belowground biomass of woody or non-woody vegetation (t $CO_2e$)

$B_{AG}$ Aboveground biomass of woody or non-woody vegetation (t $CO_2e$; see Sections 5.1 and 5.2)

$R$ Root:shoot ratio (t root dry matter/t shoot dry matter)

Root:shoot ratios and allometric models for estimating root biomass can be obtained from the following sources: i) Data collected from harvesting studies within the project area with direct measurements of root and shoot biomass; ii) Published peer-reviewed studies specific to the project region and vegetation type; or iii) Global default values for specific vegetation types or ecoregions e.g. from **IPCC 2019**.

## 5.4 Dead wood and litter

### 5.4.1 Baseline removals in deadwood and litter

Baseline removals in deadwood and litter can be estimated with any of the following approaches:

i. Modelling of carbon removals from deadwood and litter, following the procedures in **PT003**;
ii. Measurements in matched control areas, following the procedures in **AR-TOOL12** v3.1 Section 6.1 and 7.1. Matching criteria to be used when determine appropriate control areas are described in Table 1;or
iii. Default factors, following the procedures in **AR-TOOL12** v3.1 Section 6.2 and 7.2.

If using the procedures in **AR-TOOL12** v3.1, baseline removals in deadwood and litter are calculated with Equation 6 and Equation 7.

**Calculation of baseline removals in deadwood**

$$BR_{DW,a,y} = \sum_{t=1}^{y} \Delta C_{DW\_BSL,t}$$

*Equation 6*

Where:

$BR_{DW,a,y}$ Net GHG removals in deadwood under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{DW\_BSL,t}$ Change in carbon stock in deadwood under the baseline scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL12** v3.1)

**Calculation of baseline removals in litter**

$$BR_{LI,a,y} = \sum_{t=1}^{y} \Delta C_{LI\_BSL,t}$$

*Equation 7*

Where:

$BR_{LI,a,y}$ Net GHG removals in litter under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{LI\_BSL,t}$ Change in carbon stock in litter under the baseline scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL12** v3.1)

### 5.4.2 Project removals in deadwood and litter

*Expected project removals in deadwood and litter*

Expected project removals in deadwood and litter can be estimated with the following approach:

i. Modelling of carbon fluxes, following the procedures in **PT003**; or

ii. Default factors, following the procedures in **AR-TOOL12** v3.1 Section 6.2 and 7.2.

Expected project removals in deadwood and litter are calculated with Equation 8 and Equation 9.

*Actual project removals in deadwood and litter*

Actual project removals in deadwood and litter can be estimated with any of the following approaches:

i. Modelling of carbon fluxes following the procedures in **PT003;**
ii. Measurements in project areas, following the procedures in **AR-TOOL12** v3.1 Section 6.1 and 7.1; or
iii. Default factors, following the procedures in **AR-TOOL12** v3.1 Section 6.2 and 7.2.

If using the procedures in **AR-TOOL12** v3.1, actual project removals in deadwood and litter are calculated with Equation 8 and Equation 9.

**Calculation of project removals in deadwood**

$$PR_{DW,a,y} = \sum_{t=1}^{y} \Delta C_{DW\_PROJ,t}$$

*Equation 8*

Where:

$PR_{DW,a,y}$ Net GHG removals in deadwood under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{DW\_PROJ,t}$ Change in carbon stock in deadwood under the project scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL12** v3.1)

**Calculation of project removals in litter**

$$PR_{LI,a,y} = \sum_{t=1}^{y} \Delta C_{LI\_PROJ,t}$$

*Equation 9*

Where:

$PR_{LI,a,y}$ Net GHG removals in litter under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta C_{LI\_PROJ,t}$ Change in carbon stock in litter under the project scenario within the project area in year *t* (t $CO_2e$; from **AR-TOOL12** v3.1)

## 5.5 Soil organic carbon

### 5.5.1 Baseline removals in soil organic carbon

Baseline removals in soil organic carbon can be estimated with either of the following approaches:

i. Measurements in matched control areas using a tool approved by Plan Vivo. Matching criteria to be used when determining appropriate control areas are described in Table 1;
ii. Process-based modelling following the procedures in **PT001** or **PT003**;
iii. Assuming removals in soil organic carbon under the baseline scenario are zero for afforestation, reforestation and agroforestry activities that meet the applicability criteria in **AR-ACM003** v2.0 (or **AR-AM0014** v3.0 for mangroves), or if it can be demonstrated using **PT004** that land in the project area is degraded and degrading; or
iv. Applying a credible and conservative default factor from a peer-reviewed published source.

If using the procedures in **PT001** (Option ii), project removals in soil organic carbon are calculated with Equation 10.

**Calculation of baseline removals in soil organic carbon**

$$BR_{SO,a,y} = \sum_{t=1}^{y} -1 \cdot BE_{SO_t} \cdot A$$

*Equation 10*

Where:

$BR_{SO,a,y}$ Net GHG removals in soil organic carbon under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$BE_{SO_t}$ Baseline scenario emissions from change in soil organic carbon stocks in year *t* of the verification period (t$CO_2e$/ha; from **PT001**)

$A$ Extent of the project area (ha; from **PT001**)

### 5.5.2 Project removals in soil organic carbon

*Expected project removals in soil organic carbon*

Expected project removals in soil organic carbon can be estimated with either of the following approaches:

i. Process-based modelling following the procedures in **PT001** or **PT003**,
ii. Applying the relevant default factor for afforestation and reforestation activities from **AR-TOOL16** v1.1, **AR-AMS003** (for wetlands) or **AR-AM0014** v3.0 (for mangroves), or
iii. Applying a credible and conservative default factor from a peer-reviewed published source.

If using the procedures in **PT001** (Option i), project removals in soil organic carbon are calculated with Equation 11. If using the procedures in **AR-TOOL16** v1.1 or **AR-AM0014** v3.0 (Option ii), project removals in soil organic carbon are calculated with Equation 12 or Equation 13 respectively.

**Calculation of project removals in soil organic carbon (using PT001)**

$$PR_{SO,a,y} = \sum_{t=1}^{y} -1 \cdot PE_{SO_t} \cdot A$$

*Equation 11*

Where:

$PR_{SO,a,y}$ Net GHG removals in soil organic carbon under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$PE_{SO_t}$ Project scenario emissions from change in soil organic carbon stocks in year *t* of the verification period ($tCO_2e$/ha; from **PT001**)

$A$ The extent of the project area (ha; from **PT001**)

*Actual project removals in soil organic carbon*

Actual project removals in soil organic carbon can be estimated with either of the following approaches:

i. Measurements in project areas following procedures in a tool approved by Plan Vivo,
ii. Process-based modelling following the procedures in **PT003**,
iii. Applying the relevant default factor for afforestation and reforestation activities from **AR-TOOL16** v1.1, **AR-AMS003** (for wetlands) or **AR-AM0014** v3.0 (for mangroves), or
iv. Applying a credible and conservative default factor from a peer-reviewed published source.

If using default factors from **AR-TOOL16** v1.1 or **AR-AM0014** v3.0 (Option iii), project removals in soil organic carbon are calculated with Equation 12 or Equation 13 respectively.

**Calculating project removals in soil organic carbon (using AR-TOOL16)**

$$PR_{SO,a,y} = \sum_{t=1}^{y} \Delta SOC_{AL,t}$$

*Equation 12*

Where:

$PR_{SO,a,y}$ Net GHG removals in soil organic carbon under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta SOC_{AL,t}$ Change in SOC stock in the project area, in year *t* (t $CO_2e$; from **AR-TOOL16** v1.1)

If using the procedures in **AR-AM0014** v3.0, project removals in soil organic carbon are calculated with Equation 13.

**Calculating project removals in soil organic carbon in mangroves (using AR-AM0014)**

$$PR_{SO,a,y} = \sum_{t=1}^{y} \Delta SOC_{PROJ,t}$$

*Equation 13*

$PR_{SO,a,y}$ Net GHG removals in soil organic carbon under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$\Delta SOC_{PROJ,t}$ Change in SOC stock in the project area, in year $t$ (t $CO_2e$; from **AR-AM0014** v3.0)

## 5.6 Wood products

Baseline and project removals in wood products can be estimated with the following approach:

i. Modelling following procedures in a tool approved by Plan Vivo based on the conceptual framework detailed in Winjum et al 1998.[6]

## 5.7 Harvesting

To avoid the potential for reversal of carbon benefits as a result of tree harvesting, if the baseline or project scenario includes harvesting of trees, estimation of removals in woody biomass are based on the long-term average carbon stock. Procedures for calculation of long-term average carbon stock depend on whether harvesting is part of an even-aged management or partial felling system.

### 5.7.1 Even-aged management

If the baseline or project scenario includes harvesting with even-aged management (e.g. shelterwood, seed tree or clear cutting) long-term average removals in woody biomass are calculated as the average removals over a period of at least one full rotation that includes the final harvest, as shown in Equation 14 and Equation 15.

**Calculation baseline removals in woody biomass with even-aged management**

$$BR_{WB\_LTA,a,y} = \frac{\sum_{t=1}^{z} BR_{WB,a,t}}{z}$$

*Equation 14*

[6] Winjum, J.K., Brown, S. and Schlamadinger, B., 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. Forest Science, 44(2), pp.272-284. https://doi.org/10.1093/forestscience/44.2.272

Where:

$BR_{WB\_LTA,a,y}$ Long-term average net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$BR_{WB,a,t}$ Net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* in year *t* (t $CO_2e$; see Section 5.1.2)

$z$ Number of years in one or more full rotations (years)

**Calculation of project removals in woody biomass with even-aged management**

$$PR_{WB\_LTA,a,y} = \frac{\sum_{t=1}^{z} PR_{WB,a,t}}{z}$$

*Equation 15*

Where:

$PR_{WB\_LTA,a,y}$ Long-term average GHG removals in aboveground woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$PR_{WB,a,t}$ Net GHG removals in aboveground woody biomass under the project scenario for project area *a* in year *t* (t $CO_2e$; see Section 5.1.3)

$z$ Number of years in one or more full rotations (years)

### 5.7.2 Partial felling

If the baseline or project scenario includes thinning or partial felling (e.g. single tree or group selection), long-term average net-removals in woody biomass are estimated as the minimum post-harvest removals in tree biomass, as shown in Equation 16 and Equation 17.

**Calculation of baseline removals in woody biomass with partial felling**

$$BR_{WB\_LTA,a,y} = BR_{WB,a,x}$$

*Equation 16*

Where:

$BR_{WB\_LTA,a,y}$ Maximum net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* up to year *y* (t $CO_2e$)

$BR_{WB,a,x}$ Net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* up to year *x*, where year *x* is the year between the time of the

first harvest and 50-years after the start of the baseline period that has the lowest cumulative net GHG removals in woody biomass (t $CO_2e$; see Section 5.1.2).

**Calculation of project removals in woody biomass with partial felling**

$$PR_{WB\_LTA,a,y} = PR_{WB,a,x}$$

*Equation 17*

Where:

$PR_{WB\_LTA,a,y}$ Maximum net GHG removals in aboveground woody biomass under the project scenario for project area *a* up to year *y* (t $CO_2e$)

$PR_{WB,a,x}$ Net GHG removals in aboveground woody biomass under the project scenario for project area *a* up to year *x*, where year *x* is the year between the time of the first harvest and 50-years after the initiation of the project intervention that has the lowest cumulative net GHG removals in aboveground woody biomass (t $CO_2e$; see Section 5.1.3).

# 6 Parameters

| **Data/Parameter** | $\Delta C_{TREE\_BSL,t}$ |
|---|---|
| **Units** | t $CO_2e$ |
| **Description** | Change in carbon stock in tree biomass under the baseline scenario within the project area in year *t* |
| **Equations** | Equation 1 |
| **Source** | AR-TOOL14 v4.2, excluding uncertainty adjustment. |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL14 v4.2 |
| **Purpose of Data** | Calculation of baseline removals |
| **Comments** | NA |

| **Data/Parameter** | $\Delta C_{SHRUB\_BSL,t}$ |
|---|---|
| **Units** | t $CO_2e$ |

| | |
|---|---|
| **Description** | Change in carbon stock in shrub biomass under the baseline scenario within the project area in year $t$ |
| **Equations** | Equation 1 |
| **Source** | AR-TOOL14 v4.2, excluding uncertainty adjustment |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL14 v4.2 |
| **Purpose of Data** | Calculation of baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $\Delta C_{TREE\_PROJ,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Change in carbon stock in tree biomass under the project scenario within the project area in year $t$ |
| **Equations** | Equation 2 |
| **Source** | AR-TOOL14 v4.2, excluding uncertainty adjustment |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL14 v4.2 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $\Delta C_{SHRUB\_PROJ,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Change in carbon stock in shrub biomass under the project scenario within the project area in year $t$ |
| **Equations** | Equation 2 |
| **Source** | AR-TOOL14 v4.2, excluding uncertainty adjustment |
| **Value** | NA |

| | |
|---|---|
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL14 v4.2 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $A_{HERB,t}$; $A_{HERB,t-1}$ |
| **Units** | ha |
| **Description** | Area of herbaceous vegetation in project area *a* in year $t$ or year *t*-1 |
| **Equations** | Equation 4 |
| **Source** | Measured, modelled or estimated for each project area |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Direct measurements or estimates of percentage cover in sample plots or from remote sensing data (see **PT003** and **PT004**) |
| **Purpose of Data** | Calculation of removals in non-woody biomass |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $B_{HERB,t}$; $B_{HERB,t-1}$ |
| **Units** | t $CO_2$e/ha |
| **Description** | Above-ground biomass of herbaceous vegetation in year $t$ or year $t$ -1 |
| **Equations** | Equation 4 |
| **Source** | Measured or estimated for each type of herbaceous vegetation, present; or from a credible peer-reviewed published source specific to the project region. |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Measurement from sample plots using destructive harvesting approach, or use of literature values. |

| | |
|---|---|
| **Purpose of Data** | Calculation of removals in non-woody biomass |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $B_{AG}$ |
| **Units** | t $CO_2e$ |
| **Description** | Aboveground biomass of woody or non-woody vegetation |
| **Equations** | Equation 5 |
| **Source** | Estimates of baseline or project removals in woody or non-woody biomass. |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See Sections 5.1 and 5.2 |
| **Purpose of Data** | Estimation of below-ground biomass |
| **Comments** | |

| | |
|---|---|
| **Data/Parameter** | $R$ |
| **Units** | t root dry matter/t shoot dry matter |
| **Description** | Root:shoot ratio |
| **Equations** | Equation 5 |
| **Source** | Root:shoot ratios can be obtained from the following sources: i) Data collected within the project area; ii) Published studies specific to the project region and vegetation type; or iii) Global default values for specific vegetation types or ecoregions e.g. from **IPCC 2019**. |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Established approach for estimating below ground biomass. In line with IPCC guidelines. |
| **Purpose of Data** | Estimation of below-ground biomass |
| **Comments** | |

| Data/Parameter | $\Delta C_{DW\_BSL,t}$ |
|---|---|
| Units | t $CO_2e$ |
| Description | Change in carbon stock in litter under the baseline scenario within the project area in year $t$ |
| Equations | Equation 6 |
| Source | Default factor from AR-TOOL12 v3.1 |
| Value | NA |
| Justification of choice of data or description of measurement methods and procedures applied | See AR-TOOL12 v3.1 |
| Purpose of Data | Calculation of baseline removals |
| Comments | NA |

| Data/Parameter | $\Delta C_{LI\_BSL,t}$ |
|---|---|
| Units | t $CO_2e$ |
| Description | Change in carbon stock in litter under the baseline scenario within the project area in year $t$ |
| Equations | Equation 7 |
| Source | Default factor from AR-TOOL12 v3.1 |
| Value | NA |
| Justification of choice of data or description of measurement methods and procedures applied | See AR-TOOL12 v3.1 |
| Purpose of Data | Calculation of baseline removals |
| Comments | NA |

| Data/Parameter | $\Delta C_{DW\_PROJ,t}$ |
|---|---|
| Units | t $CO_2e$ |
| Description | Change in carbon stock in deadwood under the project scenario within the project area in year $t$ |
| Equations | Equation 8 |
| Source | Default factor from AR-TOOL12 v3.1 |

| | |
|---|---|
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL12 v3.1 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $\Delta C_{LI\_PROJ,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Change in carbon stock in litter under the project scenario within the project area in year $t$ |
| **Equations** | Equation 9 |
| **Source** | Default factor from AR-TOOL12 v3.1 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL12 v3.1 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $BE_{SO_t}$ |
| **Units** | t$CO_2e$/ha |
| **Description** | Emissions from change in soil organic carbon stocks in year $t$ of the baseline scenario |
| **Equations** | Equation 10 |
| **Source** | PT001 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See PT001 |

| | |
|---|---|
| **Purpose of Data** | Calculation of baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $A$ |
| **Units** | ha |
| **Description** | Extent of the project area |
| **Equations** | Equation 10, Equation 11 |
| **Source** | PT001 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See PT001 |
| **Purpose of Data** | Calculation of baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $PE_{SO_t}$ |
| **Units** | $tCO_2e/ha$ |
| **Description** | Emissions from change in soil organic carbon stocks in year $t$ of the project scenario |
| **Equations** | Equation 11 |
| **Source** | PT001 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See PT001 v1.1 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $\Delta SOC_{AL,t}$ |
| **Units** | t $CO_2e$ |

| | |
|---|---|
| **Description** | Change in SOC stock in the project area, in year $t$ |
| **Equations** | Equation 12 |
| **Source** | AR-TOOL16 v1.1 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL16 v1.1 |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $\Delta SOC_{PROJ,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Change in SOC stock in the project area, in year $t$ |
| **Equations** | Equation 13 |
| **Source** | From **AR-AM0014** v3.0 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-AM0014 |
| **Purpose of Data** | Calculation of change in SOC in project area |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $BR_{WB,a,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Net GHG removals in aboveground woody biomass under the baseline scenario for project area $a$ in year $t$ |
| **Equations** | Equation 14 |
| **Source** | AR-TOOL14 v4.2 |
| **Value** | NA |
| **Justification of choice of data or description of measurement** | See AR-TOOL14 v4.2 |

| | |
|---|---|
| **methods and procedures applied** | |
| **Purpose of Data** | Calculation of maximum baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $z$ |
| **Units** | years |
| **Description** | Number of years in one or more full rotations |
| **Equations** | Equation 14, Equation 15 |
| **Source** | Description of baseline scenario |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | NA |
| **Purpose of Data** | Calculation of maximum baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $PR_{WB,a,t}$ |
| **Units** | t $CO_2e$ |
| **Description** | Net GHG removals in aboveground woody biomass under the project scenario for project area $a$ in year $t$ |
| **Equations** | Equation 15 |
| **Source** | AR-TOOL14 v4.2 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | See AR-TOOL14 v4.2 |
| **Purpose of Data** | Calculation of maximum project removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $BR_{WB,a,x}$ |

| | |
|---|---|
| **Units** | t $CO_2e$ |
| **Description** | Net GHG removals in aboveground woody biomass under the baseline scenario for project area *a* up to year *x*, where year *x* is the year between the time of the first harvest and 50-years after the start of the baseline period that has the lowest cumulative net GHG removals in woody biomass |
| **Equations** | Equation 16 |
| **Source** | Equation 1 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Avoids over-estimating baseline removals |
| **Purpose of Data** | Calculation of baseline removals |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $PR_{WB,a,x}$ |
| **Units** | t $CO_2e$ |
| **Description** | Net GHG removals in aboveground woody biomass under the project scenario for project area a up to year x, where year x is the year between the time of the first harvest and 50-years after the initiation of the project intervention that has the lowest cumulative net GHG removals in aboveground woody biomass |
| **Equations** | Equation 17 |
| **Source** | Equation 1 |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Avoids over-estimating project removals |
| **Purpose of Data** | Calculation of project removals |
| **Comments** | NA |

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