PV CLIMATE TOOL

PT002

Estimation of carbon benefits from REDD in community managed forest

Version 2.0
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Developed by:

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Version 2.0 of this tool was developed by The Landscapes and Livelihoods Group (TLLG) www.landscapesandlivelihoods.com, and Plan Vivo Foundation Technical Advisory Committee www.planvivo.org. It is approved for use under Version 5.0 of PV Climate

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Contents

1 Summary

This tool is for the estimation of carbon benefits from Plan Vivo projects aiming to reduce emissions from deforestation and forest degradation in community managed forests. There is no geographical restriction on the use of this tool. It includes procedures for estimating values for the following parameters.

$E_{BL,VP}$ Baseline scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO_2e; see Section 5.6.1)

$AE_{BL,VP}$ Actual baseline scenario emissions from deforestation and forest degradation during verification period *VP* (t CO_2e; see Section 5.6.2)

$E_{PS,VP}$ Expected project scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO_2e; see Section 5.7.1)

$AE_{PS,VP}$ Actual emissions from deforestation and forest degradation that occurred in the project area during verification period *VP* (t CO_2e; see Section 5.7.2)

$E_{LK,VP}$ Leakage emissions expected to result from displacement of deforestation and degradation during verification period *VP* (t CO_2e; see Section 5.8.1)

$AE_{LK,VP}$ Maximum potential leakage emissions that could have occurred as a result of displacement of deforestation and degradation during verification period *VP* (t CO_2e; see Section 5.8.2)

Procedures are described for estimating expected emissions or carbon benefits at the start of a verification period, and for verification of emissions or carbon benefits at the end of the verification period.

Projects using this tool must:

- Provide spreadsheets demonstrating that all calculations have been made according to the relevant equations; and
- Provide a full description of all data and parameters used, with sufficient evidence to demonstrate that they meet the requirements described in Section 5.9.

The information used for estimates at the start of the verification period should be presented in a Project Design Document (PDD). At the time of verification, the relevant calculations and data used for verification of carbon benefits must be included in an annual report submitted to Plan Vivo.

2 Sources

This tool can be used in conjunction with the following Plan Vivo methodology and modules:

PM001 Agriculture and Forestry Carbon Benefit Assessment Methodology, Version 1.0

PU002 Estimation of Baseline and Project GHG Emissions from Carbon Pools in Plan Vivo Projects, Version 1.0

PU004 Estimation of GHG Emissions from Leakage in Plan Vivo Projects, Version 1.0

PU005 Estimation of Uncertainty of Carbon Benefit Estimates in Plan Vivo projects, Version 1.0

3   Definitions

Deforestation
Conversion from forest to non-forest

Degraded forest
Forest that has had its biomass reduced by natural or anthropogenic disturbances

Forest
Accepted national definitions for the country within which the project is located should be used if these specify 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. If an accepted national definition that meets this requirement is not met the following definition should be applied: "Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent". Forest does not include land that is predominantly under agriculture or urban

Forest stratum
An area of forest with the same forest type, legal classification, and topographic class

Leakage area
An area of forest within the reference region that could be affected by leakage

Non-forest
Land that falls outside the minimum criteria for being considered forest

Reference period
A period of time over which historical rates of deforestation and forest degradation are assumed to provide an indication of likely rates of deforestation and forest degradation during the project period

Reference region
A region encompassing the project area, that is defined by a physical or political boundary, that includes at least twice the area of each forest type and legal classification within the project area, and that is assumed to be affected similar drivers of deforestation and degradation to the project area under the baseline scenario

4   Applicability Conditions

4.1   Project Interventions

The procedures described in this tool can be applied to a broad range of geophysical and socioeconomic contexts. The main applicability criterion is that it should be applied to community managed forest. It should be noted however that users will be required to demonstrate and justify that the data and parameters used meet the requirements described in Sections 5 and 5.9 and will not result in an overestimation of carbon benefits.

This tool is applicable to project areas that meet all of the following conditions:

- Most of the variation in tree biomass is explained by forest type, and
- The main factors affecting drivers of deforestation and forest degradation in the project area are used to define forest strata.

This approach cannot be used for project areas that meet any of the following conditions:

- The baseline scenario includes planned deforestation that is documented in land management or planning documents, or
- The baseline scenario includes effective community management.

4.2   Certificate Types

This tool can be used by projects claiming rPVCs or vPVCs. It cannot be used to claim fPVCs.

5   Procedures

5.1   Project Boundaries

To apply this tool, projects must define a reference region, leakage area and reference period for each project area.

5.1.1   Reference region

Forest strata are defined according to their exposure to drivers of deforestation and forest degradation (see Section 5.2). It is, therefore, assumed that forest close to the project area will be exposed to similar drivers of deforestation and degradation as forest of the same strata within the project area, and that patterns of deforestation and degradation that occurred in the reference region during the reference period are likely to occur in forest of the same strata in the project area during the project period. The project area should not be included in the reference region so that changes in the reference region can compared to those in the project area.

A reference region must be defined for each project area, with maps and datafiles describing the reference region boundaries, must be included in the PDD. [1] A justification for why the reference region was selected, demonstrating that it meets the requirements below, must also be provided. Note that reference regions that are too large (for example national boundaries) are unlikely to exposed to similar drivers of deforestation and degradation as the project area, and smaller reference regions (for example using district or provincial boundaries) are likely to be more appropriate.

The reference region must:
- Be located as close as possible to the project area;
- Have had at least twice the area of each forest stratum present within the project area and leakage area at the start of the reference period (i.e. if the project area includes 200 ha of a forest stratum, the reference area must have had at least 600 ha of that stratum at the start of the reference period);
- Be exposed to similar drivers of deforestation and forest degradation as the project area under the baseline scenario.

If the project start date is after the end of the reference period, the project area can be included in the reference region. Otherwise, the project area must be excluded from the reference region.

The reference region does not need to be a contiguous area.

The reference region is established at the start of the project and is not usually revised unless new evidence suggests that it is no longer appropriate, or there are changes that mean parts of the reference area are no longer exposed to similar drivers of deforestation and forest degradation as the project area under the baseline scenario.

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[1] Datafiles must be in vector format, with distinct delineation of each stratum and corresponding feature attributes within designated columns. The projection system employed must also be specified.

5.1.2   Leakage area

The area susceptible to leakage will depend on the stakeholders and activities with potential to be displaced.

A leakage area for each project area, with maps and datafiles describing the leakage area boundaries, must be included in the PDD. A justification for why the leakage area was selected, with reference to the agents and drivers of deforestation and degradation whose activities could be displaced as a result of project activities. Justification for why the leakage area was selected, demonstrating that it meets the requirement below, must also be provided.

The leakage area must:

- Be defined according to the activities of specific stakeholder groups expected to engage in activities that cause deforestation or degradation in the project area under the baseline scenario, whose activities could be displaced as a result of project activities.

The leakage area does not need to be a contiguous area.

The leakage area is established at the start of the project and is not usually revised unless new evidence suggests that it is no longer appropriate.

5.1.3   Reference period

For each project area a reference period within which historical deforestation and forest degradation will be assessed in the reference region must be specified. Justification for why the reference period was selected, demonstrating that it meets all of the requirements below, must also be provided.

The reference period must:

- Have a minimum duration of 4-years and a maximum during of 12-years. A minimum of 4-years is required to reduce the effects of inter-annual variation on the average annual area deforested or degraded. A maximum of 12-years helps to ensure that the patterns of land cover change in the reference period reflect drivers of deforestation and degradation that are likely to be present during the verification period;
- End within 2 years of the start of the verification period. The reference period must be updated throughout the project period to ensure this requirement is met for each verification period; and
- Include patterns of deforestation and degradation that are likely to continue during the project period.

5.2   Stratification

To apply this tool, forest in the project area, reference region and leakage area must be stratified into strata that reflect differences in tree biomass and exposure to drivers of deforestation and forest degradation. Factors to consider when determining appropriate strata for a project area include:

- **Forest type.** Classification of forest type should reflect the main differences in tree biomass that occur in the project area. These are likely to include ecological types as well as disturbance history. Forest types that differ in their average tree biomass density by more than 10% should be treated as separate strata. Different forest types are also likely to be affected differently by drivers of deforestation and degradation.
- **Legal classification**. The legal status of the forest and the activities that are legally permitted in the area are likely to affect how the forest is used; additional classifications can be added

to reflect other relevant factors, for example efficacy of protection or enforcement, or land ownership.

- **Topography and Soils**. Topography is often an important determinant of how forest is used as it effects potential alternative land uses, and accessibility. Soil type may also be important to consider if it affects suitability for conversion to other land uses.
- **Accessibility**. Forest that is less accessible is less likely to be deforested and degraded. Factors to consider in stratification could therefore include distance from roads or rivers, or other factors affecting access by potential agents of deforestation and forest degradation.

The PDD must clearly identify the factors and classes used for defining forest strata, and justify why these are appropriate in the context of the project area. This should include a description of local agents and drivers of deforestation and forest degradation in the baseline scenario. Maps and tables describing the location and extent of all strata in the project area, reference region and leakage area must also be provided.

5.3   Carbon Stock Estimation

Projects must provide a robust estimate of carbon density in each forest stratum, and of degraded forest and non-forest. These can be defined using forest inventory techniques following standard operating procedures that are aligned with national guidelines or international best practice for the forest types surveyed. Alternatively, existing studies that provide robust estimates of carbon stocks in the forest types present within the project area and leakage area can be applied.

Carbon density values must include the above-ground woody biomass, additional carbon pools that can optionally be included are:

- aboveground non-woody biomass
- belowground biomass
- dead wood
- litter
- soil organic carbon

For each stratum, the PDD must include all of the following:
- An average carbon density (in tC/ha)
- Details of the source of values used, and a justification for why the values adopted are expected to be conservative when applied to the project area. If unpublished research is cited copies of the relevant reports should be provided as an Annex to the PDD.
- Full details of any carbon surveys conducted including survey and analysis methodologies, raw data, and estimates of uncertainty associated with carbon density values.

5.4   Land Cover Change Assessment

To determine the area of each forest stratum in the project area, reference region and leakage area at the start of the project, how they are expected to change during under the baseline scenario, and how they change under the project scenario, a series of land cover maps are required. A time series of land cover maps that describes all forest strata can be used, alternatively analysis of remote sensing imagery can be used to generate land cover maps following established techniques. Land cover maps derived from remote sensing data must use imagery with a spatial resolution of 30m or higher and have an accuracy greater than 80%. The same data sources and mapping approaches must be used to produce all land cover maps, to ensure comparability when estimating land cover change. If projects use annual composites to produce land cover maps, all images used should have cloud cover of less

than 30%, and land cover maps compared between years must be derived from images that are either from the same season or reflect the same aspects of seasonality.

As a minimum land cover maps must be available for the start and end of the reference period, and the start of each verification period.

The PDD must describe the datasets and methodologies used to generate land cover maps, with sufficient detail that they could be repeated by a suitably qualified technician

Land cover change assessment completed by comparing land cover maps for different time periods is used for defining the following parameters for the reference region, project area and leakage area:

Reference region

A_{RR_i} Area of forest stratum *i* within the reference region at the start of the reference period (ha)

A_{Def_i} Area of forest stratum *i* in the reference region converted to non-forest during the reference period (ha)

A_{Deg_i} Area of forest stratum *i* in the reference region converted to degraded forest during the reference period (ha)

AA_{Def_i} Area of forest stratum *i* in the reference region converted to non-forest during the verification period (ha)

AA_{Deg_i} Area of forest stratum *i* in the reference region converted to degraded forest during the verification period (ha)

Project area

A_{PA_i} Area of forest stratum *i* present in the project area at the start of the verification period (ha)

D_{PA_i} Area of forest stratum *i* within the project area that was deforested during the verification period (ha)

G_{PA_i} Area of forest stratum *i* within the project area that was degraded during the verification period (ha)

Leakage area

A_{LA_i} Area of forest stratum *i* present in the leakage area at the start of the verification period (ha)

D_{LA_i} Area of forest stratum *i*, within the leakage area that was deforested during the verification period (ha)

G_{LA_i} Area of forest stratum *i* within the leakage area that was degraded during the verification period (ha)

5.5 Assumptions

For describing the expected effectiveness of project interventions, and potential leakage; conservative assumptions are applied for the first verification period. These assumptions must then be updated for subsequent verification periods, based on observed effectiveness and leakage.

PDDs must therefore include all of the following:

- An estimate of expected effectiveness of project activities in reducing emissions from deforestation and forest degradation, expressed as a proportion of baseline scenario emissions that can conservatively be expected to be avoided as a result of project activities (F). Justification for the value selected must also be provided, demonstrating that the value is likely to be conservative.
- An estimate of expected emissions from deforestation and forest degradation that result from displacement of activities from the project area as a result of project activities, expressed as a proportion of carbon benefits that are expected to be lost as a result of leakage (L). Justification for the value selected must also be provided, demonstrating that the value is likely to be conservative.

The final annual report of each verification period must include all of the following:

- A value for F that will be applied in the following verification period, with details of how this was estimated based on observed effectiveness of project activities.
- A value for L that will be applied in the following verification period, with details of how this was estimated based on observed leakage.

5.6   Baseline Scenario Emissions

Baseline scenario emissions are estimated at the start of each verification period, and verified at the end of each verification period, using the approaches described below.

5.6.1   Expected baseline scenario emissions

Expected baseline scenario emissions are estimated at the start of each verification period, and verified at the end of each verification period, using the approaches described below.

To estimate baseline scenario emissions, it is assumed that if the project area is not brought under effective community management it will be affected by similar drivers of deforestation and forest degradation to other areas of forest in a reference region that have similar exposure to the main drivers of deforestation and forest degradation.

It is further assumed that the average annual amount of deforestation and forest degradation observed during a historical reference period (expressed as a proportion of forest area present at the start of the reference period), in areas of forest in the reference region that have similar exposure to the main drivers of deforestation and forest degradation as forest in the project area, will provide a conservative estimate of the annual amount of deforestation and degradation (expressed as a proportion of forest area present at the start of the verification period) that would occur in the project area under the baseline scenario.

On the basis of these assumptions, the baseline scenario emissions are estimated at the start of each verification period with Equation 1 to Equation 3.

The average annual amount of deforestation and degradation in the reference region during the reference period, as a proportion of the forest area present at the start of the reference period, is calculated for each of the forest strata present in the project area with Equation 1 and Equation 2.

Calculation of expected baseline rate of deforestation

$$D_{RR_i} = \frac{A_{Def_i}}{(A_{RR_i} \cdot T_{RP})}$$

Equation 1

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Where:

D_{RR_i} Average proportion of the forest area present in the reference region at the start of the reference period for forest stratum *i* that was deforested in each year of the reference period

A_{Def_i} Area of forest stratum *i* in the reference region converted to non-forest during the reference period (ha; see Section 5.4)

A_{RR_i} Area of forest stratum *i* within the reference region at the start of the reference period (ha; see Section 5.4)

T_{RP} Length of the reference period (years; see Section 5.1.3)

Calculation of expected baseline rate of forest degradation

$$G_{RR_i} = \frac{A_{Deg_i}}{(A_{RR_i} \cdot T_{RP})}$$

Where:

G_{RR_i} Average proportion of the forest area present in the reference region at the start of the reference period for forest stratum *i* that was degraded in each year of the reference period

A_{Deg_i} Area of forest stratum *i* in the reference region converted to degraded forest during the reference period (ha; see Section 5.4)

A_{RR_i} Area of forest stratum *i* within the reference region at the start of the reference period (ha; see Section 5.4)

T_{RP} Length of the reference period (years; see Section 5.1.3)

The baseline scenario CO_2 emissions expected to result from deforestation and forest degradation in the project area during the verification period, assuming that the average annual proportions of initial forest area deforested and degraded estimated with Equation 1 and Equation 2 occur within the project area, are calculated with Equation 3.

Calculation of expected baseline scenario emissions from deforestation and forest degradation

$$E_{BL,VP} = T_{VP} \cdot CF_{CO2} \cdot \sum_i \left(\left(D_{RR_i} \cdot A_{PA_i} \cdot (C_i - C_{NF}) \right) + \left(G_{RR_i} \cdot A_{PA_i} \cdot (C_i - C_{SF_i}) \right) \right)$$

Where:

$E_{BL,VP}$ Baseline scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO_2e)

T_{VP} Length of the verification period (years)

CF_{CO2} Conversion factor to convert from carbon to carbon dioxide based on molecular weights of carbon and carbon dioxide (44/12)

D_{RR_i},   Average proportion of the forest area present in the reference region at the start of the reference period for forest stratum *i* that was deforested in each year of the reference period (see Equation 1)

A_{PA_i} Area of forest stratum *i* present in the project area at the start of the verification period (ha; see Section 5.4)

C_i Carbon density of forest stratum *i* (t C/ha; see Section 5.3)

C_{NF} Carbon density of non-forest (t C/ha; see Section 5.3)

G_{RR_i} Average proportion of the forest area present in the reference region at the start of the reference period for forest stratum *i* that was degraded in each year of the reference period (see Equation 2)

C_{SF_i} Carbon density of degraded forest of forest stratum *i* (t C/ha; see Section 5.3)

5.6.2 Actual baseline scenario emissions

At the end of each verification period expected baseline scenario emissions must be verified by comparing the baseline emissions expected during the verification period E_{BL} to a revised estimate of baseline emissions that occurred during the verification period. The actual baseline scenario emissions that would have occurred during the verification period (AE_{BL}) are estimated by considering deforestation and degradation that occurred within the reference region during the verification period, with Equation 4 to Equation 6.

Calculation of actual baseline rate of deforestation

$$AD_{RR_i} = \frac{AA_{Def_i}}{AA_{RR_i}}$$

Equation 4

Where:

AD_{RR_i} Proportion of forest stratum within the reference region that was deforested during the verification period

AA_{Def_i} Area of forest stratum *i* in the reference region converted to non-forest during the verification period (ha; see Section 5.4)

AA_{RR_i} Area of forest stratum *i* present within the reference region at the start of the verification period (ha; see Section 5.4)

Calculation of actual baseline rate of forest degradation

$$AG_{RR_i} = \frac{AA_{Deg_i}}{AA_{RR_i}}$$

Equation 5

Where:

AG_{RR_i} Proportion of forest stratum *i* within the reference region that was degraded during the verification period

AA_{Deg_i} Area of forest stratum *i* in the reference region converted to degraded forest during the verification period (ha; see Section 5.4)

AA_{RR_i} Area of forest stratum *i* present within the reference region at the start of the verification period (ha; see Section 5.4)

Calculation of actual baseline scenario emissions from deforestation and forest degradation

$$AE_{BL,VP} = CF_{CO2} \cdot \sum_i \left(\left(AD_{RR_i} \cdot A_{PA_i} \cdot (C_i - C_{NF}) \right) + \left(AG_{RR_i} \cdot A_{PA_i} \cdot (C_i - C_{SF_i}) \right) \right)$$

Equation 6

Where:

$AE_{BL,VP}$ Actual baseline scenario emissions from deforestation and forest degradation during verification period *VP* (t CO₂e)

CF_{CO2} Conversion factor to convert from carbon to carbon dioxide based on molecular weights of carbon and carbon dioxide (44/12)

AD_{RR_i} Proportion of forest stratum within the reference region that was deforested during the verification period (see Equation 4)

A_{PA_i} Area of forest stratum *i* present in the project area at the start of the verification period (ha; see Section 5.4)

C_i Carbon density of forest stratum *i* (t C/ha; see Section 5.3)

C_{NF} Carbon density of non-forest (t C/ha; see Section 5.3)

AG_{RR_i} Proportion of forest stratum *i* within the reference region that was degraded during the verification period (see Equation 5)

C_{SF_i} Carbon density of degraded forest of forest stratum *i* (t C/ha; see Section 5.3)

5.7   Project Scenario Emissions

Expected project scenario emissions are estimated for the first verification period by employing a conservative assumption about the likely impacts of project activities on baseline scenario emissions. At the end of each verification period, actual project scenario emissions are estimated and used to verify emission reductions achieved during the previous verification period, and to update expected project scenario emissions for the subsequent verification period. The approaches for estimating expected project scenario emissions, and verifying project scenario emissions that are achieved, are described below.

5.7.1   Expected project scenario emissions

Expected project scenario emissions are estimated with Equation 7.

$$E_{PS,VP} = E_{BL,VP} \cdot (1 - F)$$

Equation 7

Where:

$E_{PS,VP}$ Expected project scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO₂ e)

$E_{BL,VP}$ Baseline scenario emissions from deforestation and forest degradation expected during the verification period (t CO₂e; see Equation 3)

F Expected effectiveness of project activities in reducing emissions from deforestation and forest degradation, expressed as a proportion of baseline scenario emissions that can conservatively be expected to be avoided as a result of project activities (See Section 5.5).

For the first verification period, a conservative value of F should be adopted. For subsequent verification periods, the value adopted for F should be informed by the actual effectiveness (AF) achieved in previous verification periods (see Section 5.7.2).

5.7.2   Actual project scenario emissions

At the end of each verification period actual project scenario emissions should be estimated using Equation 8 and Equation 9.

$$AF = \frac{CF_{CO2} \cdot \sum_i \left(\left(D_{PA_i} \cdot (C_i - C_{NF}) \right) + \left(G_{PA_i} \cdot (C_i - C_{SF_i}) \right) \right)}{AE_{BL}}$$

Equation 8

Where:

AF Actual effectiveness of project activities in reducing emissions from deforestation and forest degradation, expressed as a proportion of actual baseline scenario emissions

CF_{CO2} Conversion factor to convert from carbon to carbon dioxide based on molecular weights of carbon and carbon dioxide (44/12)

D_{PA_i} Area of forest stratum *i* within the project area that was deforested during the verification period (ha; see Section 5.4)

C_i Carbon density of forest stratum *i* (t C/ha; see Section 5.3)

C_{NF} Carbon density of non-forest (t C/ha; see Section 5.3)

G_{PA_i} Area of forest stratum *i* within the project area that was degraded during the verification period (ha; see Section 5.4)

C_{SF_i} Carbon density of degraded forest of forest stratum *i* (t C/ha; see Section 5.3)

AE_{BL} Actual baseline scenario emissions from deforestation and forest degradation during the verification period (t CO_2e; see Equation 6)

$$AE_{PS.VP} = AE_{BL} \cdot AF$$

Equation 9

Where:

$AE_{PS,VP}$ Actual emissions from deforestation and forest degradation that occurred in the project area during verification period *VP* (t CO_2e)

AE_{BL} Actual baseline scenario emissions from deforestation and forest degradation during the verification period (t CO_2e; see Equation 6)

AF Actual effectiveness of project activities in reducing emissions from deforestation and forest degradation, expressed as a proportion of actual baseline scenario emissions (see Equation 8)

5.8   Leakage Emissions

Leakage emissions are estimated at the start of each verification period, and verified at the end of each verification period, using the approaches described below.

5.8.1   Expected leakage emissions

Expected leakage emissions are estimated with a conservative estimate of the proportion of carbon benefits that could be lost through leakage using Equation 10.

$$E_{LK,VP} = L \cdot (E_{BL,VP} - E_{PS,VP})$$

Equation 10

Where:

$E_{LK,VP}$ Leakage emissions expected to result from displacement of deforestation and degradation during verification period *VP* (t CO$_2$e)

L Expected emissions from deforestation and forest degradation that result from displacement of activities from the project area as a result of project activities, expressed as a proportion of carbon benefits that are expected to be lost as a result of leakage (see Section 5.5)

$E_{BL,VP}$ Baseline scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO$_2$e; see Equation 3)

$E_{PS,VP}$ Expected project scenario emissions from deforestation and forest degradation expected during verification period *VP* (t CO$_2$e; see Equation 7)

For the first verification period, a conservative value of L should be adopted. For subsequent verification periods the value adopted for L should be informed by the actual effectiveness ($AE_{LK,VP}$) achieved in previous verification periods (see Equation 13).

5.8.2   Actual leakage emissions

To verify leakage emissions at the end of the verification period, leakage is monitored in a leakage area defined according to the mobility of stakeholders whose activities could be displaced. Deforestation and degradation that occurred within the leakage area is then compared to the deforestation and degradation within the rest of reference region, and leakage emissions are calculated with Equation 11 to Equation 13.

$$AE_{LA,VP} = CF_{CO2} \cdot \sum_i \left(\left(D_{LA_i} \cdot (C_i - C_{NF}) \right) + \left(G_{LA_i} \cdot (C_i - C_{SF_i}) \right) \right)$$

Equation 11

Where:

$AE_{LA,VP}$ Actual emissions from deforestation and degradation that occurred in the leakage area during verification period *VP* (t CO$_2$e)

CF_{CO2} Conversion factor to convert from carbon to carbon dioxide based on molecular weights of carbon and carbon dioxide (44/12)

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D_{LA_i}　　　Area of forest stratum *i*, within the leakage area that was deforested during the verification period (ha; see Section 5.4)

C_i　　　Carbon density of forest stratum *i* (t C/ha; see Section 5.3)

C_{NF}　　　Carbon density of non-forest (t C/ha; see Section 5.3)

G_{LA_i}　　　Area of forest stratum *i* within the leakage area that was degraded during the verification period (ha; see Section 5.4)

C_{SF_i}　　　Carbon density of degraded forest of forest stratum *i* (t C/ha; see Section 5.3)

$$EE_{LA,VP} = CF_{CO2} \cdot \sum_i \left(\left(AD_{RR_i} \cdot A_{LA_i} \cdot (C_i - C_{NF}) \right) + \left(AG_{RR_i} \cdot A_{LA_i} \cdot (C_i - C_{SF_i}) \right) \right)$$

Equation 12

Where:

$EE_{LA,VP}$　　　Expected emissions from deforestation and degradation in the leakage area during verification period *VP* if no leakage occurred (t CO_2e)

CF_{CO2}　　　Conversion factor to convert from carbon to carbon dioxide based on molecular weights of carbon and carbon dioxide (44/12)

AD_{RR_i}　　　Proportion of forest stratum within the reference region that was deforested during the verification period (see Equation 4)

A_{LA_i}　　　Area of forest stratum *i* present in the leakage area at the start of the verification period (ha; see Section 5.4)

C_i　　　Carbon density of forest stratum *i* (t C/ha; see Section 5.3)

C_{NF}　　　Carbon density of non-forest (t C/ha; see Section 5.3)

AG_{RR_i}　Proportion of forest stratum *i* within the reference region that was degraded during the verification period (see Equation 5)

C_{SF_i}　　　Carbon density of degraded forest of forest stratum *i* (t C/ha; see Section 5.3)

$$AE_{LK,VP} = AE_{LA,VP} - EE_{LA,VP}$$

Equation 13

Where:

$AE_{LK,VP}$　　　Maximum potential leakage emissions that could have occurred as a result of displacement of deforestation and degradation during verification period *VP* (t CO_2e)

$AE_{LA,VP}$　　　Actual emissions from deforestation and degradation that occurred in the leakage area during verification period *VP* (t CO_2e; see Equation 11)

$EE_{LA,VP}$　　　Expected emissions from deforestation and degradation in the leakage area during verification period *VP* if no leakage occurred (t CO_2e; see Equation 12)

5.9 Uncertainty

5.9.1 Uncertainty of Carbon Stock Estimates

If carbon stocks are estimated using sampling approaches, uncertainty of the carbon stock estimate at a 90% confidence level (U_x) must be determined following the procedures in **PU005** v1.0.

If secondary data are used to estimate the carbon density of forest strata, the reported uncertainty as a percentage of the carbon density value can be applied as U_x in **PU005** v1.0, if uncertainty was estimated at a 90% confidence level or above.

If the uncertainty of secondary data is not reported, or is reported with a confidence level lower than 90%, the value applied for U_x in **PU005** v1.0 must be set to 50%.

5.9.2 Uncertainty of Modelled Carbon Baseline

The carbon baseline defined in this tool is based on an extrapolation of historic deforestation and forest degradation in a reference that is matched to the forest strata within the project area. The tool requires a linear extrapolation that cannot be adjusted to predict a higher rate of deforestation and forest degradation than occurred in the reference region during the reference period.

The uncertainty associated with modelled carbon baseline is therefore assumed to be zero, so the value U_x. in **PU005** is determined as described in Section 5.9.1 without any additional adjustment for model uncertainty.

6   Parameters

Data/Parameter	A_{Def_i}
Units	Hectares
Description	Area of forest stratum *i* in the reference region converted to non-forest during the reference period
Equations	Equation 1
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying deforestation.
Purpose of Data	To estimate the annual proportion of different forest strata deforested in the reference region during the reference period.
Comments	The PDD must include full details of the land cover change analysis including: • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the reference region at the start and end of the reference period and/or a map showing land cover change during the reference period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician

	The land cover change assessment must be repeated, and A_{Def_i} estimated for each forest stratum present in the project area, at the start of each verification period. The details above must be included in the last annual report of each verification period.

Data/Parameter	A_{RR_i}
Units	Hectares
Description	Area of forest stratum *i* within the reference region at the start of the reference period
Equations	Equation 1, Equation 2
Source	Land cover assessment from analysis of remote sensing imagery or forest cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	Land cover maps provide a transparent and repeatable method for estimating the area of forest strata.
Purpose of Data	To estimate the annual proportion of different forest strata deforested and degraded in the reference region during the reference period.
Comments	The PDD must include full details of the land cover assessment including: • The value for each forest stratum in the project area; • A map of forest strata in the reference region at the start of the reference period; • A description of the datasets and methodologies used to generate land cover maps, with sufficient detail that they could be repeated by a suitably qualified technician The assessment of forest cover at the start of the reference period must be repeated, and A_{RR_i} estimated for each forest stratum present in the project area at the start of each verification period, so that the values represent the new reference period. The details above must be included in the last annual report of each verification period.

Data/Parameter	T_{RP}
Units	Years
Description	Length of the reference period
Equations	Equation 1, Equation 2
Source	Defined for each reference region (see Section 5.1.3)
Value	From 4 to 12 years
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.4
Purpose of Data	Calculating average annual proportion of the forest area present at the start of the reference region deforested and degraded during the reference period.
Comments	See Section 5.4

Data/Parameter	A_{Deg_i}
Units	Hectares
Description	Area of forest stratum *i* in the reference region converted to degraded forest during the reference period
Equations	Equation 2
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying forest degradation.
Purpose of Data	To estimate the annual proportion of different forest strata degraded in the reference region during the reference period.
Comments	The PDD must include full details of the land cover change analysis including: • The definition of forest degradation applied; • Details of how degradation was quantified; • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the reference region at the start and end of the reference period and/or a map showing land cover change during the reference period; and • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician. The land cover change assessment must be repeated, and A_{Deg_i} for each forest stratum present in the project area estimated for the new reference period at the start of each verification period. The details above must be included in the last annual report of each verification period.

Data/Parameter	T_{VP}
Units	Years
Description	Length of the verification period
Equations	Equation 3
Source	Defined by the project (see Section 5.1)
Value	From 1 to 5 years.
Justification of choice of data or description of measurement methods and procedures applied	Projects must be verified at least every 5-years.
Purpose of Data	Calculation of expected baseline scenario emissions from deforestation and forest degradation
Comments	NA

Data/Parameter	A_{PA_i}
Units	Hectares
Description	Area of forest stratum *i* present in the project area at the start of the verification period
Equations	Equation 3, Equation 6
Source	Land cover assessment from analysis of remote sensing imagery or land cover maps from within 2 years of the start of the verification period (see Section 5.4).
Value	Estimated for each forest stratum in the project area.
Justification of choice of data or description of measurement methods and procedures applied	Appropriate and accurate maps representing land cover at the start of the verification period provide a transparent and repeatable method for assessing the area of different forest strata present
Purpose of Data	Estimating the amount of deforestation and forest degradation expected during the verification period.
Comments	The PDD must include full details of the land cover assessment including: • The value for each forest stratum in the project area; • A map of forest strata in the project area at the start of the verification period; and • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover assessment, with sufficient detail that they could be repeated by a suitably qualified technician. The land cover assessment must be repeated and A_{PA_i} estimated for each forest stratum in the project area at the start of each verification period. The details above must be included in the last annual report of each verification period.

Data/Parameter	C_i; C_{SF_i}; C_{NF}
Units	tC/ha
Description	Carbon density of forest stratum *i*; Carbon density of degraded forest of forest stratum *I*; Carbon density of non-forest
Equations	Equation 3, Equation 6, Equation 8, Equation 11, Equation 12
Source	Local or regional carbon stock survey (see Section 5.3)
Value	Estimated for each project area.
Justification of choice of data or description of measurement methods and procedures applied	Where existing studies provide estimates of carbon stocks in the forest types present within the project area that are likely to provide a conservative estimate of carbon density in the project area, inventory of sample plots within the project area may not be necessary. If local or regional studies are not available or provide values that are unlikely to provide conservative estimates if applied to the project area, inventory plots and/or remote sensing analysis may be required.
Purpose of Data	Estimating the change in carbon stocks that results from deforestation and forest degradation.
Comments	The PDD must include: • Values for each forest type in the project area

	• Details of the source of values used, and a justification for why the values adopted are expected to be conservative when applied to the project area. If unpublished research is cited copies of the relevant reports should be provided as an Annex to the PDD. • Full details of any carbon surveys conducted including survey and analysis methodologies, raw data, and estimates of uncertainty associated with carbon density values. Usually estimated once at the start of the project, although can be updated if new data become available during the project.

Data/Parameter	AA_{Def_i}
Units	Hectares
Description	Area of forest stratum *i* in the reference region converted to non-forest during the verification period.
Equations	Equation 4
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying deforestation.
Purpose of Data	To estimate the annual proportion of different forest strata deforested in the reference region during the verification period.
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the reference region at the start and end of the verification period and/or a map showing land cover change during the verification period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician.

Data/Parameter	AA_{RR_i}
Units	Hectares
Description	Area of forest stratum *i* present within the reference region at the start of the verification period.
Equations	Equation 4, Equation 5
Source	Land cover assessment from analysis of remote sensing imagery or forest cover maps (see Section 5.4).
Value	Estimated for each forest stratum in the project area.
Justification of choice of data or description of	Land cover maps provide a transparent and repeatable method for estimating the area of forest strata.

measurement methods and procedures applied	
Purpose of Data	To estimate the annual proportion of different forest strata deforested and degraded in the reference region during the verification period.
Comments	The PDD must include full details of the land cover assessment including: • The value for each forest stratum in the project area; • A maps of forest strata in the reference region at the start of the verification period; • A description of the datasets and methodologies used to generate land cover maps, with sufficient detail that they could be repeated by a suitably qualified technician The assessment of forest cover at the start of the verification period must be repeated, and AA_{RR_i} estimated for each forest stratum present in the project area at the start of each verification period. The details above must be included in the last annual report of each verification period.

Data/Parameter	AA_{Deg_i}
Units	Hectares
Description	Area of forest stratum *i* in the reference region converted to degraded forest during the verification period
Equations	Equation 5
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	State the data/parameter value (if any)
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying forest degradation.
Purpose of Data	To estimate the annual proportion of different forest strata degraded in the reference region during the verification period.
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the reference region at the start and end of the reference period and/or a map showing land cover change during the verification period; and • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician.

Data/Parameter	F
Units	Unitless

Description	Expected effectiveness of project activities in reducing emissions from deforestation and forest degradation, expressed as a proportion of baseline scenario emissions that can conservatively be expected to be avoided as a result of project activities.
Equations	Equation 7
Source	Conservative assumption for the first verification period, which should be updated for subsequent verification periods with reference to actual effectiveness achieved to date (see Section 5.5).
Value	Estimated for each project area
Justification of choice of data or description of measurement methods and procedures applied	A conservative estimate for project effectiveness should reduce the likelihood that projects will under-achieve on expected emission reductions.
Purpose of Data	Estimation of expected project scenario emissions.
Comments	The PDD must specify the value adopted for F for the first verification period and justify why this is conservative for the project area. The last annual report of each reference period must specify the value of F that will be adopted for the following verification period.

Data/Parameter	D_{PA_i}
Units	Hectares
Description	Area of forest stratum i within the project area that was deforested during the verification period.
Equations	Equation 8
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4).
Value	Estimated for each forest stratum in the project area.
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying deforestation.
Purpose of Data	To estimate the actual effectiveness of project activities during the verification period.
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the project area at the start and end of the verification period and/or a map showing land cover change during the verification period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician.

Data/Parameter	G_{PA_i}
Units	Hectares
Description	Area of forest stratum i within the project area that was degraded during the verification period

Equations	Equation 8
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4).
Value	Estimated for each forest stratum in the project area.
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying deforestation.
Purpose of Data	To estimate the actual effectiveness of project activities during the verification period.
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the project area and a spreadsheet with the calculations; • Maps of forest strata in the project area at the start and end of the verification period and/or a map showing land cover change during the verification period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician

Data/Parameter	L
Units	Unitless
Description	Expected emissions from deforestation and forest degradation that result from displacement of activities from the project area as a result of project activities, expressed as a proportion of carbon benefits that are expected to be lost as a result of leakage
Equations	Equation 10
Source	Conservative assumption for the first verification period, which should be updated for subsequent verification periods with reference to actual leakage in previous verification periods (see Section 5.5)
Value	Estimated for each project area
Justification of choice of data or description of measurement methods and procedures applied	A conservative estimate for expected leakage should reduce the likelihood that projects will over-estimate expected carbon benefit
Purpose of Data	Estimation of expected leakage emissions
Comments	The PDD must specify the value adopted for L for the first verification period and justify why this is conservative for the project area. The last annual report of each reference period must specify the value of L that will be adopted for the following verification period.

Data/Parameter	D_{LA_i}
Units	Hectares
Description	Area of forest stratum i, within the leakage area that was deforested during the verification period

Equations	Equation 11
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.3)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying deforestation.
Purpose of Data	To estimate the actual leakage during the verification period
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the leakage area and a spreadsheet with the calculations; • Maps of forest strata in the leakage area at the start and end of the verification period and/or a map showing land cover change during the verification period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician

Data/Parameter	G_{LA_i}
Units	Hectares
Description	Area of forest stratum *i* within the leakage area that was degraded during the verification period.
Equations	Equation 11
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying forest degradation.
Purpose of Data	To estimate the actual leakage during the verification period
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: • The value for each forest stratum in the leakage area and a spreadsheet with the calculations; • Maps of forest strata in the leakage area at the start and end of the verification period and/or a map showing land cover change during the verification period; • A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician.

Data/Parameter	A_{LA_i}
Units	Hectares

Description	Area of forest stratum *i* present in the leakage area at the start of the verification period
Equations	Equation 12
Source	Land cover change assessment from analysis of remote sensing imagery or a time-series of land cover maps (see Section 5.4)
Value	Estimated for each forest stratum in the project area
Justification of choice of data or description of measurement methods and procedures applied	An appropriate and accurate land cover change assessment provides a transparent and repeatable method for identifying forest degradation.
Purpose of Data	To estimate the actual leakage during the verification period.
Comments	The last annual report of each verification period must include full details of the land cover change analysis including: - The value for each forest stratum in the leakage area and a spreadsheet with the calculations; - Maps of forest strata in the leakage area at the start and end of the verification period and/or a map showing land cover change during the verification period; - A description of the datasets and methodologies used to generate land cover maps and/or conduct the land cover change assessment, with sufficient detail that they could be repeated by a suitably qualified technician.

7   References

PM001 Agriculture and Forestry Carbon Benefit Assessment Methodology, Version 1.0. PV Climate Methodology. Available from: https://www.planvivo.org/pv-climate-methodologies

PU002 Estimation of Baseline and Project GHG Emissions from Carbon Pools in Plan Vivo Projects, Version 1.0. PV Climate Module. Available from: https://www.planvivo.org/pv-climate-methodologies

PU004 Estimation of GHG Emissions from Leakage in Plan Vivo Projects, Version 1.0. PV Climate Module. Available from: https://www.planvivo.org/pv-climate-methodologies

PU005 Estimation of Uncertainty of Carbon Benefit Estimates in Plan Vivo projects, Version 1.0. PV Climate Module. Available from: https://www.planvivo.org/pv-climate-methodologies