Carbon stock changes and greenhouse gas emissions from unplanned deforestation (BL-UP)

I. SCOPE, APPLICABILITY, AND OUTPUT PARAMETERS

Scope

This module allows for estimating carbon stock changes and GHG emissions related to unplanned deforestation in the baseline case (AUDD[1]). Degradation is not considered under this module. The module is mandatory for the unplanned deforestation category.

Applicability

The module is applicable for estimating baseline emissions from unplanned deforestation (conversion of forest land to non-forest land in the baseline case). The following conditions must be met to apply this module. The forest landscape configuration can be mosaic, transition or frontier.

- The module shall be applied to all project activities where the baseline agents of deforestation: (i) clear the land for settlements, crop production (agriculturalist) or ranching, where such clearing for crop production or ranching does not amount to large scale industrial agriculture activities[2]; (ii) have no documented and uncontested legal right to deforest the land for these purposes; and (iii) are either resident in the region (reference region—cf. section 1 below) or immigrants.
- It shall be demonstrated that post-deforestation land use shall not constitute reforestation

1 **Avoiding Unplanned Deforestation and Degradation (AUDD)** reduces net GHG emissions by stopping deforestation and/or degradation of degraded to mature forests that have been expanding historically or will expand in the future, in a frontier, mosaic or transition configuration.
   a. Frontier configurations are described as any landscape in which none of the forest in the project area has current direct physical connection with areas anthropogenically deforested.
   b. Mosaic configurations are described as any landscape in which no patch of forest in the project area exceeds 1000 ha and the forest patches are surrounded by anthropogenically cleared land
   c. Transition configurations are any landscape that do not meet the definition of mosaic or frontier.

2 Small-scale / Large-scale agriculture to be defined and justified by the project

- Where, pre-project, unsustainable fuelwood collection is occurring within the project boundaries modules BL-DFW and LK-DFW shall be used to determine potential leakage[3].

Parameters

This module provides procedures to determine the following parameters:

Parameter	SI Unit	Description
$\Delta C_{BSL,unplanned}$	tCO_2-e	Net greenhouse gas emissions in the baseline from unplanned deforestation
$\Delta C_{BSL,LK,unplanned}$	tCO_2-e	Net CO_2 emissions in the baseline from unplanned deforestation in the leakage belt
$A_{BSL,PA,unplanned,t}$	ha yr^{-1}	Projected area of unplanned baseline deforestation in the Project Area in year *t*
$A_{BSL,LK,unplanned,t}$	ha yr^{-1}	Projected area of unplanned baseline deforestation in the Leakage Belt Area in year *t*

II. PROCEDURE

The baseline will be developed using the following procedure. The baseline shall be revisited at fixed 10 year intervals from the start of the project except where a baseline revision has been triggered[4].

The methodology is divided into four parts:

PART 1. DEFINITION OF BOUNDARIES

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[3] Where a project claims no fuelwood collection was occurring this shall be evidenced through a PRA process. Where fuelwood collection is claimed to be sustainable, the following criteria must in the absence of the project be met:

a. The land area remains a forest; and
b. Sustainable management practices are undertaken on these land areas to ensure, in particular, that the level of carbon stocks on these land areas does not systematically decrease over time (carbon stocks may temporarily decrease due to harvest); and
c. Any national or regional forestry and nature conservation regulations are complied with.

This definition follows the CDM: EB 23, Annex 18. Additional emission reductions cannot be claimed for application of BL-DFW within the boundaries as defined in BL-UP.

[4] Forest scarcity relative to the baseline deforestation rate will trigger an immediate baseline revision where five or more years have passed since the beginning of the baseline period. Where less than five years have passed, a baseline revision shall be triggered to occur exactly five years after the beginning of the baseline period.

PART 2. ESTIMATION OF ANNUAL AREAS OF UNPLANNED DEFORESTATION

PART 3. LOCATION AND QUANTIFICATION OF THREAT OF UNPLANNED DEFORESTATION

PART 4. ESTIMATION OF CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSIONS

Parts 2 and 3 are not completely consecutive and aspects of each will be completed in parallel.

PART 1. DEFINITION OF BOUNDARIES

The analytical domain from which information on the historical deforestation rate is extracted and projected into the future must be delineated by spatial and temporal boundaries.

1.1 Definition of the spatial boundaries of the analytical domain

The boundaries of the following spatial features must be defined:

- 1.1.1 Reference region
  - 1.1.1.1 Reference region for projecting deforestation rate
  - 1.1.1.2 Reference region for projecting location of deforestation
- 1.1.2 Project area
- 1.1.3 Leakage belt

For each spatial feature, the criteria used to define their geographic boundaries must be described and justified. Vector or raster files, maps, GPS coordinates or any other locational information that allows the unambiguous identification of boundaries must be available.

Key features of each of the spatial areas are summarized in the table below:

	Mandatory?	Forested %	Area Limitations
Project area	Yes	100% at start of project	-
Leakage belt	No; see LK-ASU	100% at start of project	≥90% of project (except see 1.1.3)
RRD – reference area rate	Yes	100% at start of historical reference period	≥*MREF* (see 1.1.1.1) May not contain project area or leakage belt
RRL – reference area location	No; see Step 3.0	≥50% at start of project	Forested proportion must = *RRD* ± 25% at the start of project. Must contain project area and

	leakage belt

1.1.1 Reference region

The boundary of the reference region is the spatial delineation of the analytic domain from which information about regional rates and spatial patterns of deforestation are obtained, projected into the future and monitored. The reference region shall be representative of the general patterns of unplanned deforestation that are influencing the project area and its leakage belt as defined below.

There are two types of reference region with relevance to unplanned deforestation projects:

1. Reference region for projecting rate of deforestation (*RRD*);
2. Reference region for projecting location of deforestation (*RRL*).[5]

The two regions may overlap or may be two distinct areas.

For each of the reference regions, the minimum size (*MREF*) shall never be less than the project area, but the exact area of the reference region will depend on the size of the project and must be calculated as detailed in the following sections.

1.1.1.1 Reference region for projecting rate of deforestation (RRD)

The reference region for projecting rate of deforestation does not need to be contiguous with, and shall not encompass, the project area or the leakage belt. The area shall be equal to or greater than *MREF*. The *RRD* can be composed of several parcels that do not have to be contiguous; however, the total area of *RRD* must be forested at the start of the historical reference period (section 1.2). In the broader region encompassing the *RRD* there will likely be non-forested areas, roads, settlements, and the like.

The area of the *RRD* shall be calculated as follows[6]:

$$MREF = RAF * PA \qquad (1)$$

$$RAF = 7500 * PA^{-0.7} \qquad (2)$$

If RAF as calculated using equation 2 is <1, RAF shall be made equal to 1

Where:

MREF Minimum size of reference region for projecting rate of deforestation; ha

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5 A *RRL* is only required where location analysis is required or elected (see Step 3.0).

6 The relationship was developed from data on reference area and project area in Brown et al. 2007. Baselines for land-use change in the tropics: application to avoided deforestation projects. Mitigation and Adaptation Strategies for Climate Change, 12:1001-1026), from practical experience with pilot projects, and from expert opinion.

PA Unplanned deforestation project area; ha

RAF Reference Area Factor. Factor by which project area is multiplied to derive minimum reference area; dimensionless

The boundary of the reference region for projecting rate of deforestation must be defined using the following criteria:

a. **The main agent(s) of deforestation** in the *RRD* at the start of the historical reference period must be the same as those expected to cause deforestation in the project area during the project term[7]. Such determination can be accomplished by:

- a qualitative assessment, opinion of local experts or literature sources to demonstrate the proportion of agriculturalist versus ranchers is the same ±20% in the reference region as in the project area,
- rapid assessment techniques for determination of lack of legal rights to use land is the same in the reference region as in the project area, and
- rapid assessment techniques for determination of proportion of agents resident in the local area (lived in area > 5yr) versus immigrants (lived in area < 5yr) is the same ±20% in the reference region as in the project area.

b. **Landscape factors** of forest types, soil types, slope and elevation classes: These factors can be determined by analysis of spatial databases (e.g. vegetation map, soil suitability map, DEM [Digital Elevation Model] for slope and elevation) in a GIS for both the project area and *RRD*.

- Forest classes[8] must be present in the project area in the same proportion as in the *RRD* (±20%) at the start of the historical reference period.
- Soil types that are suitable for the land-use practice used by the main agent(s) of deforestation must be present in the project area in the same proportion as in the *RRD* (±20%).
- The ratio of slope classes "gentle" (slope <15%) to "steep" (slope ≥15%) in the project area shall be the same as the ratio in the *RRD* (±20%).

7 For instance, if deforestation pressure on the project area is linked to population growth of small farmers practicing subsistence agriculture on land that is considered marginal for commercial agriculture, areas outside the project boundary that are subject to deforestation by large cattle ranchers and cash-crop growers should not be included in the reference region. However, if the forest land within the project boundary is suitable for deforestation agents that have not encroached into the project area historically (e.g. large cattle ranchers and cash-crop growers) but that may do so during the project term, then the reference region must include areas where such agents have been deforesting during the historical reference period.

8 Defined as the broad classes that are observable in remote sensing imagery from differences in spectral characteristics that can be confirmed on the ground. The same classes shall be used throughout Parts 2 and 3 of BL-UP

- Elevation classes (500m classes) in the project area shall be in the same proportion as in the *RRD* (±20%).

c. **Transportation networks and human infrastructure,** such as roads, navigable rivers and settlements, that increase the likelihood of deforestation and that exist historically in the *RRD* must be directly comparable to those that are expected to exist within the project area during the project term.

The following conditions shall be met:

- Where navigable rivers are present in the project area, navigable river/stream density (m/km^2) is the same (±20%) for the *RRD* and the project area.
- Road density (m/km^2) is the same (±20%) for the *RRD* at the start of the historical reference period as for the project area, including a buffer around the project area of at least 1 km.
- Settlement density ($settlements/km^2$) is the same (±20%) for non-forested areas in a 1 km buffer around the project area at the start of the baseline period as in 1 km buffer zones around parcels (if more than one) in the *RRD* at the start of the historical reference period.

d. **Social factors** having an impact on land-use change patterns within the *RRD* and the project area must be the same or have the same effect at the start of the historical reference period. Examples can include presence of gangs or guerillas, or the ethnic composition of local populations.

e. **Policies and regulations** having an impact on land-use change patterns within the *RRD* and the project area must be of the same type or have an equivalent effect at the start of the historical reference period, taking into account the current level of enforcement. This means that where sub-national administrative units are governed by a different set of land-use regulations, it is necessary to ensure that the boundary of the *RRD* does not cross into another sub-national unit that does not have equivalent policies or regulations.

f. **Exclusion of planned deforestation**. Areas of planned deforestation shall be excluded from the reference region boundaries where evident[9].

[9] e.g. Mining concessions, industrial agriculturalists, large-scale public works

Where insufficient forest area exists in the country to equal *MREF* while meeting criteria a through f, then *MREF* shall be made equal to the area that meets criteria a through f. Where the forest area meeting criteria a through f is less than ½ of *MREF*, then the requirements for similarity in criteria a, b and c shall be relaxed from **±**20% to **±** 30%. If it remains impossible to define a region for *RRD* that is at least ½ of *MREF* then criterion e shall be relaxed so that policies and regulations having an impact on land-use change patterns within the *RRD* and the project area must be of the same type or have an equivalent effect five years prior to the start of the baseline period (rather than at the start of the historic reference period). In this final situation, in step 2.2 an increasing rate of deforestation shall not be used.

1.1.1.2 Reference region for projecting location of deforestation (RRL)

The area of the reference region for projecting location of deforestation (*RRL*) must be a single parcel, contiguous with and including the project area and the leakage belt. *RRL* shall consist of a minimum of 5% non-forest and a minimum of 50% forest. The area of forest in the *RRL* shall be equal to the area of the *RRD* (±25%).

The boundary of *RRL* shall be based on as simple an outline as possible and not include spatial deviations from the most parsimonious shape without evidence justifying why the deviation or exclusion does not result in bias in spatial projection of deforestation location.

At the start of the baseline period, *RRL* must have the same proportion of forests suitable for conversion to the land-use practices of the deforestation agents as the project area (±30%) as demonstrated by soil suitability, precipitation regime, elevation and access to markets.

RRL shall exclude areas of protected forest where the protected status is enforced.

Note that a reference region for projection of location of deforestation (*RRL*) is only required where location analysis is required or elected (see Step 3.0).

1.1.2 Project area

The project area is the discrete parcel(s) of land that are under threat of deforestation on which the project developers will undertake the project activities and that are forest land at the start date of the REDD project activity. Lands on which the REDD project activities will not be undertaken or that have not entered in the baseline assessment are not to be included in the project area.

The project area itself shall be 100% forested at time zero.

1.1.3 Leakage Belt

Depending on the methods chosen to address leakage caused by activity displacement, a leakage belt may have to be defined in the surroundings or immediate vicinity of the project area. See the LK-ASU to decide whether a leakage belt is required.

If a leakage belt is defined, a baseline deforestation rate must be estimated for it using the procedures described in this module.

The leakage belt must conform with the following criteria:

a. The leakage belt area must be the forest areas closest to the project area meeting the minimum area requirement and meeting the criteria listed here.

b. All parts of the leakage belt must, at a minimum, be accessible and reachable by project baseline deforestation agents with consideration of agent mobility.

c. The belt must not be spatially biased in terms of distance of edge of belt from edge of project area without justification based on agent mobility or criteria for landscape and transportation listed below.

d. Landscape factors - These factors can be determined by analysis of spatial databases (e.g. vegetation map, soil suitability map, DEM [Digital Elevation Model] for slope and elevation) in a GIS for both the project area and reference region.

    - Forest types must be present in the leakage belt in the same proportion as in the project area (±20%).
    - Soil types that are suitable for the land-use practice used by the main agent(s) of deforestation in the project area must be present in the leakage belt in the same proportion as the project area (±20%).
    - The ratio of slope classes "gentle" (slope <15%) to "steep" (slope ≥15%) in the project area shall be (± 20%) the same of the ratio in the leakage belt.
    - Elevation classes (500m classes) in the leakage belt shall be in the same proportion as in the project area (± 20%).

e. Transportation factors -

    The following conditions shall be met:

    - Where navigable rivers/streams are present in the project area, navigable river/stream density (m/km^2) is the same (±20%) for the leakage belt and the project area.
    - Road density (m/km^2) is the same (±20%) for the leakage belt as for the projected density (in the baseline period) for the project area (including a buffer around the project area of at least 1 km and up to the total project area).
    - Settlement density (settlements/km^2) is the same (±20%) for non-forested areas in a 1km buffer around the project area as in 1 km buffer zones around forested areas in the leakage belt.

f. Policies and regulations having an impact on land-use change patterns within the leakage belt and the project area must be of the same type or have the same effect, taking into account the current level of enforcement. This means that where sub-national administrative units are governed by a different set of land-use regulations, it is necessary to ensure that the boundary of the leakage belt does not cross into another sub-national unit that does not have equivalent policies or regulations.

g. Social factors having an impact on land-use change patterns within the leakage belt and the project area must be the same or have the same effect. Examples can include presence of gangs or guerillas, or the ethnic composition of local populations.

Minimum leakage belt area:

The minimum leakage belt area shall be equal to at least 90% of the area of the project. However, if identification of a forested area of this size (meeting criteria a to g) is impossible then the following guidelines shall be followed:

Forest Area Meeting Criteria a-g (Relative to Project Area)	**Relaxation of Similarity Requirements in Criteria d and e**	**Leakage Belt Area**
≥ 90%	None (±20% is used)	≥ 90% of the project area
≥75% - 89%	None (±20% is used)	Available forest area meeting criteria a – g
< 75%	Relaxation from: ±20% to ±50%	Available forest area meeting criteria g – g (with similarity requirements in d and e relaxed to ±50%)

1.2 Temporal boundaries

The following temporal boundaries must be defined (see also the "REDD Methodology Framework" – REDD-MF):

- **Start date and end date of the historical reference period[10].** The historical reference period shall at a minimum be defined by the years between the three spatial data points (see 2.1.1)
- **Start date and end date of the REDD project crediting period.**
- **Date at which the project baseline will be revisited**. The baseline must be renewed every 10 years after the start of the project, except where forest scarcity has led to a trigger for baseline revision (see step 2.4).

Note: Any ACR definitions or guidance that are or will become inconsistent with the definitions of this module shall supersede the definitions in this module.

[10] Historical reference period shall always end ≤ 2 years prior to project start date

PART 2. ESTIMATION OF ANNUAL AREAS OF UNPLANNED DEFORESTATION

The procedure is implemented by applying the following four steps:

STEP 2.1 Analysis of historical deforestation

STEP 2.2 Estimation of the annual areas of unplanned baseline deforestation in the *RRD*

STEP 2.3 Estimation of the annual areas of unplanned baseline deforestation in the project area

STEP 2.4 Analysis of deforestation constraints

STEP 2.1 Analysis of historical deforestation

This step is to quantify the historical deforestation rate during the historical reference period within the *RRD*. This is performed by implementing the following sub-steps:

2.1.1 Collection of appropriate data sources

2.1.2 Mapping of historical deforestation

2.1.3 Calculation of the historical deforestation rate

2.1.4 Map accuracy assessment

2.1.1 Collection of appropriate data sources

Collect the data that will be used to analyze deforestation during the historical reference period within the *RRD*. This should be done for at least three time points, at least 3 years apart to obtain sufficient data for calibrating and testing the goodness of fit of a deforestation model[11] with historical deforestation data.

As a minimum requirement:

- Collect medium resolution remotely sensed spatial data[12] (30m x 30m resolution or less, such as Landsat, Resourcesat-1 or Spot sensor data) for three points in time of no less than 3 years apart covering no more than 12 years (with the first point in time being no more than 2 years from the project start date). Three time points over a maximum of 12 years must be included, however, additional points either within or beyond the 12 year period may be added to enhance the deforestation analysis.
- For the first point in time from the project start date, collect high-resolution data from remote sensors (<5 x 5 m pixels) and/or from direct field observations for ground-

11 This is required for PART 3 - Location and quantification of the threat of unplanned baseline deforestation.

12 Guidance on the selection of data sources (such as remotely sensed data) can be found in Chapter 3A.2.4 of the IPCC 2006 GL AFOLU and in GOFC-GOLD. (2009), Section 2.1.

truthing the medium resolution data collected in previous step. These data must be of sufficient quantity to produce a map that shall have an accuracy of no less than 90% in the classification of forest vs non-forest as per Step 2.1.4.

Where already interpreted data of adequate spatial and temporal resolution and accuracy are available and meet the requirements defined in this module, these can be used instead of collecting new original data.

2.1.2 Mapping of historical deforestation[13]

Using the data collected in Step 2.1.1 divide the reference region (*RRD*) into polygons[14] representing "forest" land and "non-forest" land at different dates in the past[15] (*Forest Cover Maps*) as well as "deforested" land (*Deforestation Maps*) at different time periods in the past. Deforestation Maps showing areas of deforestation with paired data shall be prepared and available for the time periods between each historic image.

Given the heterogeneity of methods, data sources, and software, no specific methodology is prescribed for forest land and deforestation mapping. However, good practice of remote sensing analysis has to be followed in any case[16]. Mapping methods for each map type (forest / deforestation) have to be able to generate consistent datasets.

Consistent with the applicability condition, areas of planned deforestation shall be identified and excluded from both the *Forest Cover Maps* and the *Deforestation Maps*.

2.1.3 Calculation of the historical deforestation

The outcome of the calculations must be the area of forest at the beginning and end of the historical reference period, and the number of hectares deforested for each interval of the historical reference period. Gross deforestation shall be measured rather than net deforestation.

Calculating the area of deforestation when maps have gaps due to cloud cover is a challenge. The use of multiple-date images for the same 12 month period can significantly reduce cloud cover, and the cloud cover in the final images must be no more than 10% of any image. If there are clouds in either date in question in the area for which the rate is being calculated, then the rate should come from areas that were cloud free in *both* dates in question. This should be estimated in hectares per year.

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13 Note: For the purpose of this module, mapping forest and non-forest land is sufficient. However, project participants may consider to divide these two classes in sub-classes representing different carbon densities, as long as such classes can be accurately mapped using the data collected in Step 2.1 and such mapping is useful for other methodology steps.

14 Data formats can be either raster or vector (line, point, or polygon); data in raster format can be converted to vector formats and vice versa.

15 Note that non-forest land will not exist in RRD at the start of the historical reference period but will be present in subsequent points in time during the period

16 For example, Sourcebook on REDD (GOFC-GOLD 2009).

2.1.4 Map accuracy assessment

A verifiable accuracy assessment of the maps (AA_U) produced in the previous sub-step is necessary to produce a credible estimate of the historical deforestation rate[17].

The minimum map accuracy shall be 90% for both the "forest" class and the "non-forest" class.

If the classification accuracy is less than 90% then the map is not acceptable for further analysis. More remote sensing data and ground truthing data will be needed to produce a product that reaches the 90% minimum mapping accuracy.

Where interpretation of historical remote sensing products is included in this step, it may not be possible to perform an accuracy assessment of the past image(s). If field data, aerial photographs or high resolution imagery (resolution ≤ 5m) are available for the applicable time period these shall be used. If no field data, aerial photographs or high resolution images exist it is assumed that the classification algorithm used for the most recent image to achieve 90% or more accuracy of the map product is applicable to the past images and will achieve the same accuracy.[18]

STEP 2.2 Estimation of the annual areas of unplanned baseline deforestation in the *RRD*

The modeled annual area of deforestation in *RRD* ($A_{BSL,RRD,unplanned,t}$) shall be calculated across the historical reference period. The methodology provides three approaches:

1. Historical average annual deforestation during the historical reference period
2. A linear regression of deforested area against time
3. A non-linear regression of deforested area against time

To be applied, any regression must be significant ($p \leq 0.05$), must have an $r^2 \geq 0.75$ and must be free from bias (demonstrated through selection of the fit with the lowest residuals). If five or more points in time are used in the analysis then a non-linear regression may be used, if there are less than five points the regression shall be linear.

There are only three acceptable forms of regression that can be used in this methodology:

a. Linear: $A_{BSL,RRD,unplanned,t} = m * \text{th} + int$

b. Non-linear

  i. Power: $A_{BSL,RRD,unplanned,t} = c * \text{th}^{b}$

  ii. Logarithmic: $A_{BSL,RRD,unplanned,t} = c * \ln(\text{th}) + b$

[17] See Chapter 5 of IPCC 2003 GPG, Chapter 3A.2.4 of IPPC 2006 Guidelines for AFOLU, and Section 2.1 of Sourcebook on REDD (GOFC-GOLD, 2009) for guidance on mapping deforestation and performing accuracy assessments.

[18] This is standard remote sensing practice and given that the algorithm is designed to distinguish between forest and non forest, and that the maximum time period over which the algorithm is assumed to be applicable is 3-5 years, this is a valid assumption.

Where:

$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in the *RRD* in year *t*; ha
th	1, 2, 3, … th^* years elapsed since the start of the historical reference period
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity
m	Slope
int	Intercept
c	Constant
b	Constant
ln	Natural logarithm function

If no significant regression results, the mean area deforested, hectares per year, across the historical reference period shall be used. If a linear regression projecting decreasing annual areas of deforestation is significant it must be used.

Where regression analysis is insignificant:

$$A_{BSL,RRD,unplanned,t} = A_{RRD,unplanned,hrp} / T_{hrp} \quad (3)$$

Where:

$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in the *RRD* in year *t*; ha
$A_{RRD,unplanned,hrp}$	Total area deforested during the historical reference period in the *RRD*; ha
T_{hrp}	Duration of the historical reference period in years; yr
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

In the case where a baseline revision has been triggered, regression analysis is insignificant, and the most recent data point shows a decrease in the area of deforestation in that interval, then the projected area of unplanned deforestation in *RRD* in year *t* ($A_{BSL,RRD,unplanned,t}$) as determined from the most recent two data points for imagery analysis shall be used and the baseline shall be revisited and updated again after another 5 year period.

When applied to the project:

- Where the mean rate is used, the same mean rate is used for each year of the baseline period
- Where a regression is used, the modeled area deforested for year 1, 2, 3, etc of the historical reference period shall be applied to years 1, 2, 3, etc of the baseline period

STEP 2.3 Estimation of annual areas of unplanned baseline deforestation in the project area

The projected unplanned baseline deforestation in the *RRL* is estimated as follows:

$$A_{BSL,RR,unplanned,t} = A_{BSL,RRD,unplanned,t} * P_{RRL} \quad (4)$$

Where:

$A_{BSL,RR,unplanned,t}$	Projected area of unplanned baseline deforestation in the reference region for location (*RRL*) in year *t;* ha
$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in *RRD* in year *t*; ha
P_{RRL}	Ratio of forest area in the *RRL* at the start of the baseline period to the total area of the *RRD*; dimensionless
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

Where spatial modeling is applied $A_{BSL,RR,unplanned,t}$ is used for annual area of deforestation.

The projected unplanned baseline deforestation in the project area is estimated as follows (only used where spatial modeling is not applied):

$$A_{BSL,PA,unplanned,t} = A_{BSL,RRD,unplanned,t} * P_{PA} \quad (5)$$

Where:

$A_{BSL,PA,unplanned,t}$	Projected area of unplanned baseline deforestation in the project area in year *t;* ha
$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in the *RRD* in year *t;* ha
P_{PA}	Ratio of the project area to the total area of *RRD*; dimensionless
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

The annual area of unplanned baseline deforestation in the leakage belt is estimated as follows (only used where spatial modeling is not applied):

$$A_{BSL,LK,unplanned,t} = A_{BSL,RRD,unplanned,t} * P_{LK} \quad (6)$$

Where:

$A_{BSL,LK,unplanned,t}$	Projected area of unplanned baseline deforestation in the leakage belt area in year *t;* ha
$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in *RRD* in year *t;* ha
P_{LK}	Ratio of the area of the leakage belt to the total area of *RRD*; dimensionless
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

$$A_{BSL,PA,unplanned} = \sum_{t=1}^{t*} A_{BSL,PA,unplanned,t} \quad (7)$$

$$A_{BSL,LK,unplanned} = \sum_{t=1}^{t*} A_{BSL,LK,unplanned,t} \tag{8}$$

Where:

$A_{BSL,PA,unplanned}$	Total area of unplanned baseline deforestation in the project area; ha
$A_{BSL,LK,unplanned}$	Total area of unplanned baseline deforestation in the leakage belt; ha
$A_{BSL,PA,unplanned,t}$	Projected area of unplanned baseline deforestation in the project area in year t; ha
$A_{BSL,LK,unplanned,t}$	Projected area of unplanned baseline deforestation in the leakage belt in year t; ha
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

STEP 2.4 Analysis of deforestation constraints

Annual deforestation areas can only be credible within the context of constraints to further deforestation in the reference region for location (*RRL*). This will be the case if it can be demonstrated that forest land suitable for the conversion to non-forest land is still available in sufficient quantity as defined in 2.4.2 below. A baseline revision shall be triggered in any situation where remaining forest area can be perceived as a limiting factor for ongoing deforestation.

2.4.1 Identification of land-use constraints

Identify the biophysical and infrastructural constraints (e.g. soil, climate, elevation, slope etc.) that limit the geographical area where deforestation agents could expand their land-use activities in current forest land. Consider the constraints as they are perceived by the main groups of deforestation agents[19]. The parameter LSC_{RRL} (the forest area in the *RRL* that is suitable for conversion to an alternate land use) is for the product of this step.

2.4.2 Identification of forest land that is suitable for deforestation

Where forest area becomes limiting to future deforestation then it can be expected that deforestation rate will fall. The following procedure determines when forest area is sufficiently limiting to trigger a baseline revision:

Using the constraints identified in Step 2.4.1, map the forest land that is suitable for the further expansion of non-forest land in the project area and estimate its area ($A_{e.d.RRL}$).

[19] This analysis may be facilitated by the maps and criteria created in PART 3.

$$A_{e.d.RRL,t} = LSC_{RRL} - \left(\sum_{t=1}^{t^*} \left(P_{LSC,RRL} * A_{BSL,RR,unplanned,t} \right) \right) \quad (9)$$

Where:

$A_{e.d.RRL,t}$	Area of forest suitable for expansion of non-forest land in *RRL* in year *t*; ha
LSC_{RRL}	The area of *RRL* suitable for conversion from forest to an alternate land use; ha
$P_{LSC,RRL}$	Ratio of the parameter LSC_{RRL} to the area of *RRD*; dimensionless
$A_{BSL,RR,unplanned,t}$	Projected area of unplanned baseline deforestation in the reference region (*RRL*) in year *t;* ha
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

A baseline revision shall be triggered under the following scenario where:

$A_{e.d.RRL,t} \quad \leq \quad 50 * A_{BSL,RR,unplanned,t}$

The baseline shall be revised immediately if five or more years have passed since the beginning of the baseline period. If less than five years have passed, the baseline revision shall be triggered to occur exactly five years after the start of the baseline period.

PART 3. LOCATION AND QUANTIFICATION OF THREAT OF UNPLANNED DEFORESTATION

All the analysis in this part of the module is performed on the reference region for location of deforestation (*RRL*). The basic steps needed to perform the analysis described above are:

STEP 3.0 Determination of whether location analysis is required

STEP 3.1 Preparation of data sets for spatial analysis

STEP 3.2 Preparation of risk maps for deforestation

STEP 3.3 Selection of the most accurate deforestation risk map using an acceptable validation metric

STEP 3.4 Mapping of the locations of future deforestation

STEP 3.0: Determination of whether location analysis is required

Whether or not a location analysis is required[20] is determined by the initial configuration of the *RRL* landscape:

a. Mosaic Configuration

   In the case of a mosaic configuration, location analysis is not required. Location analysis can still be elected to avoid the conservative approach with regard to carbon stocks. If location analysis is not elected, proceed directly to Step 3.4.

b. Transition Configuration

   In the case of a transition configuration, location analysis is not required where it can be shown that ≥ 25% of the project geographic boundary is within 50m of land that has been anthropogenically deforested within the 10 years prior to the project start date. If this criterion is not met location analysis is always required. Location analysis may always be elected to avoid the conservative approach with regard to carbon stocks. If location analysis is neither required nor elected proceed directly to Step 3.4.

c. Frontier Configuration

   In the case of a frontier configuration location analysis is always required.

STEP 3.1: Preparation of data sets for spatial analysis

3.1.1 Requirements of spatial models

Project proponents must identify the model/software that will be used to analyze where deforestation is most likely to happen in future periods[21]. The model/software used must:

- Be peer-reviewed
- Be transparent (no "black box" calculations such as neural networks)
- Incorporate spatial datasets that have been documented to explain patterns of and are correlated with deforestation (both raster and vector)
- Be able to project location of future deforestation

In addition, to the above, the models shall conform with the requirements and analyses detailed in Steps 3.1.2, 3.2, 3.3 and 3.4.2.

3.1.2 Preparation of spatial datasets

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[20] Where no location analysis is conducted, a conservative approach in the use of carbon stocks or areas deforested in the baseline is required. Specifically, the stratum with the lowest carbon stocks shall be deforested first followed sequentially by the next highest carbon stock stratum ad infinitum (see Step 3.4.1)

[21] Many models exist; examples include GEOMOD (http://www.clarklabs.org/) and Land Change Modeler (http://www.clarklabs.org/) but these models are merely examples and are neither required nor pre-approved for use.

As with the *RRD*, remote sensing data is needed for the spatial analysis. The remote sensing data shall meet the same requirements as those for the *RRD* and described in Sections 2.1.1 to 2.1.4.

Next, the spatial variables that most likely explain the pattern of deforestation in the *RRL* need to be identified. The following key classes must be considered: landscape factors, accessibility factors, anthropogenic factors, and factors related to land tenure and management. Within these classes, the following factors shall be considered at a minimum:

1. **Landscape factors**: vegetation type, soil fertility, slope, elevation
2. **Accessibility factors:** distance to navigable rivers, distance to water bodies, distance to roads (primary and secondary alone or in combination), distance to railroads
3. **Anthropogenic factors**: distance to sawmills, distance to settlements, distance to already cleared land, distance to forest edge, and
4. **Actual land tenure and management**: private land, public land, protected land, logging concession, etc.

The final analysis shall use a minimum of one factor from each of the four classes of factors given above, and create digital maps representing the *Spatial Features* of each factor (i.e. the shape files representing the point, lines or polygon features or the raster files representing surface features). Models are required to produce *Distance Maps* from the mapped features (e.g. distance to roads or distance to already cleared lands) or maps representing continuous variables (e.g. slope classes) and categorical variables (e.g. soil quality classes). For simplicity, all these maps are called "*Factor Maps*".

STEP 3.2 Preparation of deforestation risk maps

A *Risk Map* shows, for each pixel location *l*, the risk, or "suitability", for deforestation as a numerical scale (e.g. from 0 = minimum risk to some upper limit representing the maximum).

Models use different techniques to produce Risk Maps, and algorithms may vary among the different modeling tools. Algorithms of internationally peer-reviewed modeling tools are eligible to prepare deforestation risk maps provided they are shown to conform with the methodology at time of validation. In preparing deforestation risk maps, multiple simulations (can be tens of computer runs) of the model are run using different numbers and combinations of factor maps producing a number of risk maps. The next step is then to select the risk map that is the most accurate (step 3.3).

STEP 3.3 Selection of the most accurate deforestation risk map

Confirming the model output (generally referred to as model validation in the modeling community) is needed to determine which of the deforestation risk maps is the most accurate. The model output (such as a risk map) shall be confirmed through "calibration and validation", referred to here as "calibration and confirmation" (so as not to be confused with validation as required by the ACR).

Model calibration and confirmation:

Prepare for each *Risk Map* a *Prediction Map* of the deforestation in the confirmation period (e.g. between historic interval one and two, if using three remote sensing images). Overlay the predicted deforestation with locations that were actually deforested during the confirmation period. Select the Prediction Map with the best fit and identify the *Risk Map* that was used to produce it.

The map with the best fit will be the map that best reproduced actual deforestation in the confirmation period. The best fit is assessed by use of the "Figure of Merit" (FOM) that confirms the model prediction in statistical manner (Pontius *et al*. 2008; Pontius et al. 2007[22]). The FOM is a ratio of the intersection of the observed change (change between the reference maps in time 1 and time 2) and the predicted change (change between the reference map in time 1 and simulated map in time 2) to the union of the observed change and the predicted change (9). The FOM ranges from 0%, where there is no overlap between observed and predicted change, to 100% where there is a perfect overlap between observed and predicted change. The highest percent FOM and least number of factor maps used for creating the deforestation risk map must be used as the criteria for selecting the most accurate deforestation risk map to be used for predicting future deforestation.

$$FOM = \frac{CORRECT}{CORRECT + Err_A + Err_B} \tag{10}$$

Where,

CORRECT Area correct due to observed change predicted as change; ha

Err_A Area of error due to observed change predicted as persistence; ha

Err_B Area of error due to observed persistence predicted as change; ha

The minimum threshold for the best fit as measured by the Figure of Merit (FOM) must be 40% for frontier configuration, 80% for mosaic configuration, and 60% for transition configuration.[23] Where these minimum standards are not met the project shall be considered ineligible.

[22] R G Pontius Jr, W Boersma, J-C Castella, K Clarke, T de Nijs, C Dietzel, Z Duan, E Fotsing, N Goldstein, K Kok, E Koomen, C D Lippitt, W McConnell, A Mohd Sood, B Pijanowski, S Pithadia, S Sweeney, T N Trung, A T Veldkamp, and P H Verburg. 2008. Comparing input, output, and validation maps for several models of land change. Annals of Regional Science, 42(1): 11-47. R G Pontius Jr, R Walker, R Yao-Kumah, E Arima, S Aldrich, M Caldas and D Vergara. 2007. Accuracy assessment for a simulation model of Amazonian deforestation. Annals of Association of American Geographers, 97(4): 677-695.)

[23] Based on data for seven case studies in Belize, Bolivia, Brazil, Mexico, and Kalimantan (Brown et al. 2007; Harris et al. 2008, op. cit.)

STEP 3.4: Mapping of the locations of future deforestation

3.4.1 Where location analysis is not conducted

Where no location analysis is conducted (for eligibility see Step 3.0) the following conservative approach is mandatory:

Future deforestation is assumed to happen first in the strata with the lowest carbon stocks.

- Select the stratum with the lowest carbon stock (see Step 3.2.1);
- Where deforestation in year *t* (plus the deforestation already accounted in previous years) exceeds the area of the lowest carbon stock stratum proceed to the next lowest carbon stock stratum;
- Repeat the above procedure for each successive project year (or monitoring period).

Where no location analysis has been conducted, the annual deforestation area is given directly by $A_{BSL,PA,unplanned,t}$ for the project area and $A_{BSL,LK,unplanned,t}$ for the leakage belt.

The annual area deforested in the project area ($A_{BSL,PA,unplanned,t}$) and in the leakage belt ($A_{BSL,LK,unplanned,t}$) is allocated to strata as described above to give $A_{unplanned,i,t}$ which is then used in step 4.3.

3.4.2 Where location analysis (Steps 2.1, 2.2, 2.3) has been conducted

Future deforestation is assumed to happen first at the pixel locations with the highest deforestation risk value.

Where location analysis has been conducted, the area of deforestation to be used is $A_{BSL,RR,unplanned,t}$ allowing the allocation of deforested areas throughout the *RRL* based on highest likelihood of deforestation at any point in time as predicted by the spatial model. In this manner, the spatial model may lead to a larger area of deforestation in the project area than elsewhere in the *RRL*, or alternately the model may lead to a smaller area within the project area to be deforested than elsewhere in the *RRL*.

To determine the locations of future deforestation do the following:

- In the Deforestation *Risk Map,* select the pixels with the highest risk value whose total area is equal to the area expected to be deforested in project year one (or first baseline period). The result is the *Map of Baseline Deforestation for Year 1* (or first baseline period, respectively).
- Repeat the above pixel selection procedure for each successive project year (or baseline period) to produce a *Map of Baseline Deforestation* for each future project year (or monitoring period). Do this at least for the upcoming 10-year baseline period and, optionally, for the entire project duration.
- Add all yearly (or periodical) baseline deforestation maps in one single map showing the expected *Baseline Deforestation for the Baseline Period* and, optionally, *Project Duration*.

- Prepare a table showing the number of hectares that will be deforested each year in the baseline case for the baseline period in the project area. In addition, prepare a Crediting Period Baseline Deforestation Map showing the hectares projected to be deforested in each year in the fixed (10 year) baseline period.

The hectares deforested each year will be located within the defined strata and shall be summed to give $A_{unplanned,i,t}$ which is then used in step 4.3.

PART 4. ESTIMATION OF CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSIONS

The methodology procedure is divided in the following five steps:

STEP 4.1 Stratification of the total area subject to deforestation

STEP 4.2 Estimation of carbon stocks and carbon stock changes per stratum

STEP 4.3 Estimation of the sum of baseline carbon stock changes

STEP 4.4 Estimation of the sum of baseline greenhouse gas emissions

STEP 4.5 Calculation of net CO_2 equivalent emissions

STEP 4.1: Stratification

Pre-deforestation strata (forest strata)

The Module X –STR shall be used to stratify the total area subject to deforestation in the Project Area and Leakage Belt area.

Post-deforestation strata (non-forest land uses)

The areas expected to be deforested shall be separated into post-deforestation land uses. The long-term average carbon stock for post-deforestation land-uses shall be determined in Step 4.2.2. The land uses shall be justified taking into account current land uses in the reference region and observed land-uses in areas deforested during the historical reference period.

STEP 4.2: Estimation of carbon stocks and carbon stock changes per stratum

4.2.1 Forest carbon stocks

Each forest stratum will be represented by a carbon stock estimated within 2 years before the project start date, for simplicity referred to here as stocks at *t=0* (see CPES.A).

Use the methods described in the carbon pool modules (CPES.A through CPES.D) to determine the carbon stock of each forest stratum. In the situation where the baseline includes harvesting of long-lived wood products the harvested wood products carbon pool (CPES.E) shall be included.

Forest strata:

$$C_{BSL,i} = C_{AB\_tree,i} + C_{BB\_tree,i} + C_{AB\_non-tree,i} + C_{BB\_non-tree,i} + C_{DW,i} + C_{LI,i} + C_{SOC,i} \quad (11)$$

Where:

$C_{BSL,i}$	Carbon stock in all carbon pools in forest stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_tree,i}$	Carbon stock in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_tree,i}$	Carbon stock in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_non-tree,\ i}$	Carbon stock in aboveground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_nontree,I}$	Carbon stock in belowground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{DW,i}$	Carbon stock in dead wood in stratum *i*; t CO_2-e ha^{-1}
$C_{LI,i}$	Carbon stock in litter in the forest stratum *i*; t CO_2-e ha^{-1}
$C_{SOC,i}$	Carbon stock in soil organic carbon in the forest stratum *i*; t CO_2-e ha^{-1}
i	1, 2, 3, … *M* strata

Carbon pools excluded from the project can be counted as zero. For determining which carbon pools shall be included in the calculations as a minimum, see Table 1 in REDD-MF and tool T-SIG.

4.2.2 Estimation of post-deforestation carbon stocks

Post-deforestation carbon stocks are assumed to be the long-term average stocks on the land following deforestation (time-weighted average of stocks in a given cyclical post-deforestation land-uses systems such as shifting agriculture with fallow). These stocks depend on the assumed land-uses after deforestation in each post-deforestation land-use.

Two options are available to determine the carbon stocks of these land-uses:

Option 1 – Simple approach: A list of likely post-deforestation land uses shall be established taking into account land uses on areas deforested in the reference region during the historical reference period. The land uses with the highest long-term carbon stocks are conservatively considered representative of future post-deforestation land use classes. A carbon stock is calculated from the highest carbon stock land-use class and used as a proxy for all post-deforestation carbon stocks in that land use during the project term. Note that in cyclical post-deforestation land-use systems the time-weighted average of stocks in a cycle shall be used.

Option 2 – Historical area-weighted average: The historical land-use matrix will refer to post-deforestation land uses initiated during the historical reference period. An historical mix of post-deforestation land-uses is assumed to be representative of future changes. The area-weighted average of the mature carbon stock for each land use is calculated from the historical land-use change matrix and is assumed to represent all post-deforestation carbon stocks in that land use during the project term. Note that in cyclical post-deforestation land-use systems the time-weighted average of stocks in a cycle shall be used. The historical reference period shall be used as the time-frame reference.

Post-deforestation carbon stocks of the selected land-use classes shall be obtained from local studies and, where examples of mature vegetation for a particular land-use do not exist in the reference area then data shall be obtained from credible and representative literature sources (e.g. IPCC GL 2006 or other credible literature sources). The local study areas shall include sites that represent the conditions and the land management practices identified as the most likely post-deforestation baseline conditions. Local data shall be based on a sampling scheme that produces conservative estimates of the carbon stocks[24]. Where stocks accumulate through time, the mature stock shall be used and where stocks are in a cycle such as in shifting cultivation, the time-weighted average of C stocks in a cycle shall be used in option 1 and 2.

$$C_{post,i} = C_{AB\_tree,i} + C_{BB\_tree,i} + C_{AB\_nontree,i} + C_{BB\_nontree,i} + C_{DW,i} + C_{LI,i} + C_{SOC,PD-BSL,i} \qquad (12)$$

Where:

$C_{post,i}$	Carbon stock in all pools in post-deforestation stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_tree,i}$	Carbon stock in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_tree,i}$	Carbon stock in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_non\text{-}tree,i}$	Carbon stock in aboveground non-tree vegetation in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_non\text{-}tree,i}$	Carbon stock in belowground non-tree vegetation in stratum *i*; t CO_2-e ha^{-1}
$C_{DW,i}$	Carbon stock in dead wood in stratum *i*; t CO_2-e ha^{-1}
$C_{LI,i}$	Carbon stock in litter in stratum *i*; t CO_2-e ha^{-1}
$C_{SOC,PD\text{-}BSL,i}$	Mean post-deforestation stock in soil organic carbon in the post deforestation stratum *i* ; t CO_2-e ha^{-1}
i	1, 2, 3, … *M strata*

Carbon pools excluded from the project can be accounted as zero. For the determination which carbon pools shall be included in the calculations as a minimum, see Table 1 in REDD-MF and tool T-SIG.

[24] It is possible that the post-deforestation vegetation is variable and a conservative estimate would be obtained by selectively sampling the vegetation to represent the maximum C stocks present.

STEP 4.3: Estimation of the sum of baseline carbon stock changes

The sum of baseline carbon stock changes is estimated as follows:

$$\Delta C_{TOT} = C_{BSL} - C_{post} - C_{wp} \tag{13}$$

$$C_{BSL} = \sum_{t=1}^{t*}\sum_{i=1}^{M}((C_{BSL,i}) * A_{unplanned,i,t}) \tag{14}$$

$$C_{post} = \sum_{t=1}^{t}\sum_{i=1}^{M}(C_{post,i} * A_{unplanned,i,t}) \tag{15}$$

$$C_{wp} = \sum_{t=1}^{t}\sum_{i=1}^{M}(C_{WP,i} * A_{unplanned,i,t}) \tag{16}$$

Where:

ΔC_{TOT}	Sum of the baseline carbon stock change in all pools up to time *t**; t CO_2-e (calculated separately for the project area [PA] and the leakage belt [LB]
C_{BSL}	Total forest carbon stock in areas deforested; t CO_2-e
C_{post}	Total post-deforestation carbon stock in areas deforested; t CO_2-e
C_{wp}	Total carbon stock in harvested wood products; t CO_2-e
$C_{BSL,i}$	Carbon stock in all carbon pools in the forest stratum *i*; t CO_2-e ha^{-1}
$A_{unplanned,i,t}$	Area of unplanned deforestation in forest stratum *i* at time *t*; ha
$C_{post,i}$	Carbon stock in all carbon pools in the post-deforestation stratum *i*; t CO_2-e ha^{-1}
$A_{unplanned,i,t}$	Area of unplanned deforestation in post deforestation stratum *i* at time *t*; ha
$C_{WP,i}$	Mean carbon stock in wood products pool (stock remaining in wood products after 100 years) from stratum *i*; t CO_2-e ha^{-1}
t	1, 2, 3, … *t* years elapsed since the projected start of the REDD project activity
i	1, 2, 3, … *M* strata

For calculation of carbon stock sequestered in wood products, see CPES.E.

STEP 4.4: Estimation of the sum of baseline greenhouse gas emissions

The GHG emissions in the baseline within the project boundary can be estimated as:

$$GHG_{BSL,E} = \sum_{t=1}^{t^*}\sum_{i=1}^{M}\left(E_{FC,i,t} + E_{BiomassBurn,i,t} + N_2O_{direct-N,i,t}\right) \tag{17}$$

Where:

$GHG_{BSL,E}$	Greenhouse gas emissions as a result of deforestation activities within the project boundary in the baseline; t CO_2-e
$E_{FC,i,t}$	CO_2 emission from fossil fuel combustion in stratum *i* in year *t*; t CO_2-e
$E_{BiomassBurn,i,t}$	Non-CO_2 emissions due to biomass burning as part of deforestation activities in stratum *i* in year *t*; t CO_2-e
$N_2O_{direct-N,i,t}$	Direct N_2O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum *i* in year *t*; t CO_2-e
t	1, 2, 3, …t^* years elapsed since the projected start of the REDD project activity

For detailed information regarding the calculation of $E_{FC,i,t}$, $E_{BiomassBurn,i,t}$ and $N_2O_{direct-N,i,t}$ see CPES.F, CPES.G and CPES.H.

GHG emission sources excluded from the project boundary can be neglected, i.e. accounted as zero. For the determination which sources of emissions must be included in the calculations as a minimum use Table 1 in REDD-MF and tool T-SIG.

STEP 4.5: Calculation of net emissions

$$\Delta C_{BSL,unplanned} = \Delta C_{BSL,PA,unplanned} + GHG_{BSL,E} \tag{18}$$

$$\Delta C_{BSL,PA,unplanned} = \Delta C_{TOT,PA} \tag{19}$$

$$\Delta C_{BSL,LK,unplanned} = \Delta C_{TOT,LB} \tag{20}$$

Where:

$\Delta C_{BSL,unplanned}$	Net greenhouse gas emissions in the baseline from unplanned deforestation; t CO_2-e
$\Delta C_{BSL,PA,unplanned}$	Net CO_2 emissions in the baseline from unplanned deforestation in the project area; t CO_2-e
$\Delta C_{BSL,LK,unplanned}$	Net CO_2 emissions in the baseline from unplanned deforestation in the leakage belt; t CO_2-e
$GHG_{BSL,E}$	Greenhouse gas emissions as a result of deforestation activities within the project boundary in the baseline; t CO_2-e
$\Delta C_{TOT,PA}$	Sum of the baseline carbon stock change in all pools up to time *t** in the project area; t CO_2-e
$\Delta C_{TOT,LB}$	Sum of the baseline carbon stock change in all pools up to time *t** in the leakage belt; t CO_2-e

III. DATA AND PARAMETERS NOT MONITORED (DEFAULT OR MEASURED FOR BASELINE REVISION)

Data / parameter:	Any spatial feature included in the spatial model that is subject to changes over time (Factor Maps)
Data unit:	Depending on the spatial features selected
Used in equations:	
Description:	Factor Maps
Source of data:	
Measurement procedures (if any):	Update of digital maps
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	Risk Maps
Data unit:	
Used in equations:	
Description:	A *Risk Map* shows, for each pixel location *l*, the risk, or "suitability", for deforestation as a numerical scale (e.g. from 0 = minimum risk to some upper limit representing the maximum).
Source of data:	
Measurement procedures (if any):	Update of digital maps
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	Baseline Deforestation Maps
Data unit:	
Used in equations:	

Description:	Maps showing the location of deforested hectares in each year of the baseline period
Source of data:	
Measurement procedures (if any):	Update of digital maps
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	AA_U
Data unit:	%
Used in equations:	Part 2, Section 2.1.4
Description:	The accuracy assessment of the rate of unplanned deforestation (equals 90% or more)
Source of data:	Existing maps or models, expert consultation, literature
Measurement procedures (if any):	Multi-criteria analysis implemented in a Geographical Information System
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	*Correct*
Data unit:	ha
Used in equations:	10
Description:	Area correct due to observed change predicted as change
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)

QA/QC procedures:	
Any comment:	

Data / parameter:	*Err_A*
Data unit:	ha
Used in equations:	10
Description:	Area of error due to observed change predicted as persistence
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	*Err_B*
Data unit:	ha
Used in equations:	10
Description:	Area of error due to observed persistence predicted as change
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	*FOM*
Data unit:	
Used in equations:	

Description:	Figure of Merit
Source of data:	Calculated using equation 10.
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	*LB*
Data unit:	Ha
Used in equations:	
Description:	Leakage belt area
Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures (if any):	
Quality Assurance / Quality Control	Where leakage belt boundaries have not been derived using GPS on-the-ground measurements quality control shall be carried out. A minimum of 30 locations on the leakage belt boundary, each separated by at least 1km, shall be visited. If a systematic bias is detected in the original boundaries and/or if >10% of locations differ by >50m then the entire boundary shall be resurveyed
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	LSC_{RRL}
Data unit:	Ha
Used in equations:	9
Description:	The area of *RRL* suitable for conversion from forest to an alternate land use

Source of data:	
Measurement procedures (if any):	Calculated from the result of analysis of forest areas in the reference region for projection of location of deforestation with regard to constraints to deforestation (including elevation, climate, protected status etc). Uses parameter $A_{RRL,forest,t}$ derived from M-MON
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	PA
Data unit:	Ha
Used in equations:	1,2
Description:	Unplanned deforestation project area
Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	Where project boundaries have not been derived using GPS on-the-ground measurements, quality control shall be carried out. A minimum of 30 locations on the project boundary, each separated by at least 1km, shall be visited. If a systematic bias is detected in the original boundaries and/or if >10% of locations differ by >50m then the entire boundary shall be resurveyed
Any comment:	Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	P_{LK}
Data unit:	Dimensionless
Used in equations:	6

Description:	Ratio of the area of the leakage belt to the total area of *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	$P_{LSC,RRL}$
Data unit:	Dimensionless
Used in equations:	9
Description:	Ratio of the parameter LSC_{RRL} to the area of the *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	P_{PA}
Data unit:	dimensionless
Used in equations:	5
Description:	Ratio of the Project Area to the total area of *RRD*

Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	P_{RRL}
Data unit:	dimensionless
Used in equations:	4
Description:	Ratio of forest area in the ***RRL*** at the start of the historical reference period to the total area of the *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	*RRD*
Data unit:	Ha
Used in equations:	
Description:	Geographic boundaries of the reference area for projection of rate of deforestation

Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	

Data / parameter:	*RRL*
Data unit:	Ha
Used in equations:	
Description:	Geographic boundaries of the reference area for projection of location of deforestation
Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	

Data / parameter:	T_{hrp}
Data unit:	Yr
Used in equations:	3
Description:	Duration of the historical reference period in years
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance /	

Quality Control	
Any comment:	Should be between 10 and 15 years

IV. PARAMETERS ORIGINATING IN OTHER MODULES

Data / parameter:	$A_{RRD,unplanned,hrp}$
Data unit:	Ha
Used in equations:	3
Description:	Total area deforested during the historical reference period in *RRD*
Module parameter originates in:	M-MON
Any comment:	

Data / parameter:	$A_{RRL,forest,t}$
Data unit:	Ha
Used in equations:	Implicitly used in Section 2.4
Description:	Remaining area of forest in *RRL* at time *t*
Module parameter originates in:	M-MON
Any comment:	

Data / parameter:	$C_{AB\_tree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	11,12
Description:	Carbon stock in aboveground biomass in trees in stratum *i*
Module parameter originates in:	CPES.A
Any comment:	

Data / parameter:	$C_{BB\_tree,i}$
Data unit:	t CO_2-e ha^{-1}

Used in equations:	11,12
Description:	Carbon stock in belowground biomass in trees in stratum *i*
Module parameter originates in:	CPES.A
Any comment:	

Data / parameter:	$C_{AB\_nontree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	11,12
Description:	Carbon stock in aboveground non-tree vegetation in stratum *i*
Module parameter originates in:	CPES.A
Any comment:	Herbaceous vegetation considered *de minimis* in all instances

Data / parameter:	$C_{BB\_nontree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	11,12
Description:	Carbon stock in belowground non-tree vegetation in stratum *i*
Module parameter originates in:	CPES.A
Any comment:	Herbaceous vegetation considered *de minimis* in all instances

Data / parameter:	$C_{DW,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	11,12
Description:	Carbon stock in dead wood in stratum *i*
Module parameter originates in:	CPES.E
Any comment:	

Data / parameter:	$C_{LI,i}$

Data unit:	t CO_2-e ha^{-1}
Used in equations:	11,12
Description:	Carbon stock in litter in stratum *i*
Module parameter originates in:	CPES.C
Any comment:	

Data / parameter:	$C_{SOC,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	11
Description:	Carbon stock in soil organic carbon in the baseline in stratum *i*
Module parameter originates in:	CPES.D
Any comment:	

Data / parameter:	$C_{SOC,PD\text{-}BSL,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12
Description:	Mean post-deforestation stock in soil organic carbon in the post deforestation stratum *i*
Module parameter originates in:	CPES.D
Any comment:	

Data / parameter:	$C_{WP,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	16
Description:	Mean carbon stock in wood products pool (stock remaining in wood products after 100 years) from stratum *i*
Module parameter originates in:	CPES.E
Any comment:	

Data / parameter:	$E_{BiomassBurn,i,t}$
Data unit:	t CO_2-e
Used in equations:	17
Description:	Non-CO_2 emissions due to biomass burning as part of degradation activities in stratum *i* in year *t*
Module parameter originates in:	CPES.F
Any comment:	

Data / parameter:	$E_{FC,i,t}$
Data unit:	t CO_2-e
Used in equations:	17
Description:	CO_2 emission from fossil fuel combustion in stratum *i* in year *t*
Module parameter originates in:	CPES.G
Any comment:	

Data / parameter:	$N_2O_{direct-N,i,t}$
Data unit:	t CO_2-e
Used in equations:	17
Description:	Direct N_2O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum *i* in year *t*
Module parameter originates in:	CPES.H
Any comment:	

Data / parameter:	*Regional Forest Cover / Non-Forest Cover Benchmark Map*
Data unit:	
Used in equations:	
Description:	Map showing the location of forest land within the reference region at the beginning of the crediting period

Module parameter originates in:	M-MON
Any comment:	

Data / parameter:	*Project Forest Cover Benchmark Map*
Data unit:	
Used in equations:	
Description:	Map showing the location of forest land within the project area at the beginning of each monitoring period. If within the Project Area some forest land is cleared, the benchmark map must show the deforested areas at each monitoring event
Module parameter originates in:	M-MON
Any comment:	

Data / parameter:	*Leakage Belt Forest Cover Benchmark Map*
Data unit:	
Used in equations:	
Description:	Map showing the location of forest land within the leakage belt area at the beginning of each monitoring period. Only applicable where leakage is to be monitored in a leakage belt
Module parameter originates in:	M-MON
Any comment:	