VCS MODULE VMD0007
REDD METHODOLOGICAL MODULE:
ESTIMATION OF BASELINE CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSIONS FROM UNPLANNED DEFORESTATION AND UNPLANNED WETLAND DEGRADATION (BL-UP)

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Sectoral Scope 14
Methodology developed by:

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1 SOURCES

This module is one of numerous modules that comprise the VCS approved methodology VM0007: REDD Methodology Modules.

This module uses the latest version of the following modules and tools:

- VMD0015 Methods for monitoring of greenhouse gas emissions and removals in REDD project activities (M-REDD)
- Module CP-AB VMD0001 Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools
- Module CP-D VMD0002 Estimation of carbon stocks in the dead-wood pool
- Module CP-L VMD0003 Estimation of carbon stocks in the litter pool
- Module CP-S VMD0004 Estimation of carbon stocks in the soil organic carbon pool (mineral soils)
- Module CP-W VMD0005 Estimation of carbon stocks in the long-term wood products pool
- Module BL-DFW VMD0008 Estimation of baseline emission from forest degradation caused by extraction of wood for fuel
- Module LK-ASU VMD0010 Estimation of emissions from activity shifting for avoiding unplanned deforestation
- Module LK-DFW VMD0012 Estimation of emissions from displacement of fuelwood extraction
- Module E-BPB VMD0013 Estimation of greenhouse gas emissions from biomass and peat burning
- Module E-FFC VMD0014 Estimation of emissions from fossil fuel combustion
- Module E-NA CDM tool Estimation of direct N₂O emissions from nitrogen application
- Module M-TW VMD00xx Methods for monitoring of soil carbon stock changes and greenhouse gas emissions in tidal wetland restoration and conservation project activities
- Module BL-TW VMD00XX Estimation of baseline soil carbon stock changes and greenhouse gas emissions in tidal wetland restoration and conservation project activities
- Tool T-SIG CDM Tool for testing significance of GHG emissions in A/R CDM project activities
2 SUMMARY DESCRIPTION OF THE MODULE

This module allows for estimating carbon stock changes and GHG emissions related to unplanned deforestation and wetland degradation in the baseline easy-scenario (VCS eligible categories AUDD\(^1\) and AUWD, respectively) and wetland degradation (VCS category AUWD).

This module was originally developed for AUDD project activities. It is also mandatory for use in AUWD project activities and for this purpose the following translation table must be used.

<table>
<thead>
<tr>
<th>Where the module refers to:</th>
<th>It must be understood as referring to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deforestation / deforested / cleared</td>
<td>Wetland degradation / degraded / degraded</td>
</tr>
<tr>
<td>AUDD</td>
<td>AUWD</td>
</tr>
<tr>
<td>APD</td>
<td>APWD</td>
</tr>
<tr>
<td>REDD project</td>
<td>CIW project</td>
</tr>
<tr>
<td>Conversion of forest land to non-forest land</td>
<td>Conversion of intact wetland to degraded wetland or non-wetland</td>
</tr>
<tr>
<td>Forest area / forested</td>
<td>Wetland area / intact wetland</td>
</tr>
<tr>
<td>Forest class</td>
<td>Vegetation class</td>
</tr>
</tbody>
</table>

When applying BL-UP for AUWD project activities, disregard the references to Module CP-S in Part 4 and use Module BL-TW instead for soil carbon accounting. When comparing landscape factors for the reference region (Section 1.1.1.1), elevation classes must be appropriate to the use in tidal wetlands and must be justified by the project proponent. Hydrology and salinity are additional landscape factors to be considered.

The module is mandatory for the unplanned deforestation category.

3 DEFINITIONS AND ACRONYMS

Definitions

The following definitions are provided to assist the reader. In addition to the definitions set out in the VCS document Program Definitions and VCS methodology VM0007 REDD+ MF, the following definitions apply. Any definitions or guidance of the VCS that are or will become inconsistent with the definitions of this module shall out-rule the definitions in this module.

Calibration period - The first time step in the historical reference period, used to calibrate the model.

\(^1\) 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 does not meet the definition of mosaic or frontier.
Factor maps – Maps that create the spatial dataset used to project deforestation location including spatial features, distance maps and other maps which may represent continuous variables and categorical variables.

Frontier deforestation – 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.

Mosaic deforestation - 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.

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.

Risk Map – A risk map shows, for each pixel location, the risk, or “suitability”, for deforestation as a numerical scale.

Transition deforestation – Transition configurations are any landscape that does not meet the definition of mosaic or frontier.

Acronyms Used

Acronyms used in naming variables that are not used in the text of the module are not listed here. Definitions of each variable are included following the applicable formula and in the parameter section of this module for easier reference.

APWD – Avoiding Planned Wetland Degradation

AUDD – Avoiding Unplanned Deforestation and Degradation

AUWD – Avoiding Unplanned Wetland Degradation

CIW – Conservation of Intact Wetland

DEM – Digital Elevation Model

DP – Forest area that is cleared per additional person(s) entering the population

FOM – Figure of Merit

RRD – Reference region for projecting rate of deforestation

RRL – Reference region for projecting location of deforestation

MREF – Minimum size of reference region for projecting rate of deforestation
**4 APPLICABILITY CONDITIONS**

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 or aquaculture, where such clearing for crop production or ranching or aquaculture does not amount to large scale industrial agri/aquaculture activities; (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.
- 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.

**5 PROCEDURES**

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.

The methodology provides two approaches to estimating baselines, either from observed historic deforestation trends, denoted “simple historic,” or from observed (historic) relationship between population and deforestation, denoted “population driver.” Only one approach can be used (i.e., they cannot be used in combination, or used alternately within a crediting period). Applicability conditions for using the population driver approach are detailed in Part 2 below. Where methodology steps include an “alternate” step, the alternate is used when employing the population driver approach. All other steps are generally applicable and are employed using both approaches.

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

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 Module BL-DFW within the boundaries as defined in Module BL-UP.
The methodology is divided into four parts:

Part 1 DEFINITION OF BOUNDARIES

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 allow the unambiguous identification of boundaries must be available.

Key features of each of the spatial areas are summarized in the table below (see also Exhibit 1 for the population driver approach):

<table>
<thead>
<tr>
<th>Baseline rate approach</th>
<th>Mandatory?</th>
<th>Forested %</th>
<th>Area Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project area</td>
<td>Yes</td>
<td>100% at start of project</td>
<td>-</td>
</tr>
<tr>
<td>Leakage belt</td>
<td>Simple historic, No, see LK-ASU</td>
<td>100% at start of project</td>
<td>≥90% of project (except see 1.1.3)</td>
</tr>
<tr>
<td>Population driver</td>
<td>Yes</td>
<td>100% at start of project</td>
<td>None. Leakage belt is all forested area at the project start within the RRD and outside the project area (see 1.1.3 alternate)</td>
</tr>
</tbody>
</table>
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)

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 equal to 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 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 used to define the 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:

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4 A RRL is only required where location analysis is required or elected (see Step 3.0).
5 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
\[ MREF = RAF \times PA \]  
(1)

\[ RAF = 7500 \times PA^{-0.7} \]  
(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
- \( PA \): Unplanned deforestation project area; ha
- \( RAF \): Reference Area Factor. Factor to multiply times project area to get 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.\(^6\) 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 \((\pm20\%)\) 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 \(>5\) years) versus immigrants (lived in area \(<5\) years) is the same \((\pm20\%)\) in the reference region as in the project area

b. **Landscape factors** of forest types, soil types, slope and elevation classes for both the project area and RRD meet the criteria below. These factors can be determined by analysis of spatial databases (e.g., vegetation map, soil suitability map, DEM for slope and elevation) in a GIS.
   - Forest classes must be present in the project area in the same proportion as in the RRD \((\pm20\%)\) at the start of the historical reference period.\(^7\)
   - 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 \((\pm20\%)\)

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\(^6\) *Strategies for Climate Change, 12:1001-1026*, from practical experience with pilot projects, and from expert opinion. *Data in Brown S. et al. 2007.*

\(^7\) *Forest classes* are 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 must be used throughout Parts 2 and 3 of Module **BL-UP**.
• 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%)

• Elevation classes (500 m 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/km²) for the RRD is the same, less than, or does not exceed (±by more than 20%) that of the project area

• Road density (m/km²) for the RRD is the same, less than, or does not exceed by more than 20% that of the project area, including a buffer around the project area of at least 1 km, 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

• In non-forested areas around the RRD, settlement density (at the start of the historical reference period) is the same, less than, or does not exceed by more than 20% that of non-forested areas around the project area (at the start of the historical reference period). The analysis must be performed in 1 km buffer zones around parcel(s) in the RRD and a 1 km buffer around the project area. Settlement density is expressed as settlements/km². Settlement density (settlements/km²) 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 subnational 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 subnational unit that does not have equivalent policies or regulations.

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

Where insufficient forest area exists in the country to equal *MREF* while meeting criteria (a) through (f), then *MREF* shall must 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, c, d, e, and f must be met.
and c shall-must be relaxed from \(\pm 20\%/20\%\) to \(\pm 30%/30\%\). If it remains impossible to define a region for RRD that is at least \(\frac{1}{2}\) 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 not be used.

Since Equation 1 may render projects with a relatively small project areas (e.g., 50,000 ha or less) unfeasible, project proponents of such small projects may justify a smaller MREF with emphasis on avoidance of non-conservative reference regions that may help to augment the emission reduction outcome of the project.

1.1.1.1 Alternate. Reference region for projecting rate of deforestation (RRD) based on population driver

When using the population driver approach for projecting rate of deforestation, the reference region is defined as the consolidated area of population census units (see Exhibit 1) that include and surround part or all of the project area. The population census units included in the RRD must form a single contiguous area and the boundary of the RRD shall be as parsimonious a shape as possible to that of the project area. The RRD need not cover the entire project area, but no VCUs may be claimed for portions of the project area not included in the RRD. There is no minimum area requirement for the RRD. However, because activity shifting leakage from local deforestation agents is also tracked within the RRD (see Section 1.1.3 alternate), the RRD shall:

a. Include all significant forest areas surrounding (but not necessarily adjacent to) the project area that are accessible and attractive to local deforestation agents; and

b. Not be spatially biased in terms of distance of edge of the RRD from edge of project area (i.e., roughly in the middle of the RRD). For RRDs bordered by water, see exceptions outlined below

Exceptions to the above are permitted where the exclusion of any census unit from the RRD is justified on the basis of:

a. Deforestation agent mobility, with consideration of landscape and transportation

b. Prevailing directionality of deforestation agents\(^{10}\) with respect to the forested landscape, including context outside the RRD; or

c. Other appropriate regional socioeconomic factors

c.d. Subnational policy regulations. Where the consolidated area of population census units surrounding the project area crosses subnational jurisdictional borders and it can be proven that varying land-use regulations in specific census units affect the baseline scenario differently in these census units compared to the project area, these census units can be excluded from the RRD. Levels of enforcement must be taken into account when assessing these differences

The above criteria can be assessed through a qualitative assessment, opinion of local experts or literature sources.

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\(^9\) For example, by demonstrating that all the forested area in the region or country that meets all other requirements for reference regions are included.

\(^{10}\) E.g., for wetlands bordering open water where agents will not be headed out to open water.
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 tree species, 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).

**1.1.1.2 Alternate. Reference region for projecting location of deforestation (RRL) using population driver approach**

A reference region for projection of location of deforestation (RRL) is required when using the population driver approach for projecting rate of deforestation. When using the population driver approach, the area/boundary of the RRL is the same as the RRD.

**1.1.2 Project Area**

The project area is the discrete parcel(s) of land that is/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 the time zero project start date.

**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 surrounding or immediate vicinity of the project area. See the Module 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, listed below, 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 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 be met:

- Where navigable rivers/streams are present in the project area, navigable river/stream density (m/km²) is the same (±20%) for the leakage belt and the project area.
- Road density (m/km²) 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/km²) is the same (±20%) for non-forested areas in a 1 km 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 subnational 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 subnational 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 project 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:
### Sectoral Scope 14

#### Forest Area Meeting Criteria a – g (Relative to Project Area)

<table>
<thead>
<tr>
<th>Relaxation of Similarity Requirements in Criteria d and e</th>
<th>Leakage Belt Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥90%</td>
<td>None (±20% is used) ≥90% of the project area</td>
</tr>
<tr>
<td>≥75 – 89%</td>
<td>None (±20% is used) Available forest area meeting criteria a – g</td>
</tr>
<tr>
<td>&lt;75%</td>
<td>Relaxation from: ±20% to ±50% Available forest area meeting criteria a – g (with similarity requirements in d and e relaxed to ±50%)</td>
</tr>
</tbody>
</table>

### 1.1.3 Alternate. Leakage Belt using population driver approach

When using the population driver approach to project baseline rate of deforestation, the leakage belt is delineated as all forest area at project start that is within the RRD boundary and outside of the project area.

### 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.** For the simple historic approach to project rate of deforestation, the historical reference period shall, at a minimum, be defined by the years between the three spatial data points (see 2.1.1). For the population driver approach to project rate of deforestation, the historical reference period for rate, at a minimum, be defined by the years between the two or more census data points (see below) and for location- at a minimum be defined by the years between three spatial data points (Steps 3.2 and 3.3).
- **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.

**Note:** Any definitions or guidance of the VCS that are or will become inconsistent with the definitions of this module shall overrule the definitions in this module.

### PART 2. ESTIMATION OF ANNUAL AREAS OF UNPLANNED DEFORESTATION

The default approach for estimation of annual areas of unplanned deforestation is simple historic. An alternate population driver approach for estimation of annual areas of unplanned deforestation may be used instead if the following applicability conditions are met.

a. Historic census data for the RRD for population driver approach is available for 2 or more points in time in the interval 20 years prior to the project (with the last census date within 2 years of the project start date), or, official population projections are available

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11 Historical reference period shall always end ≤2 years prior to project start date.
b. Periodic population census data for the RRD for population driver approach is expected to be available over the project crediting period, with planned re-census at least every 10 years (≤10 years); and

c. Common practice is that non-forest land in the RRD is not left idle for more than 10 years (such that productive land required to accommodate a growing population cannot be met by existing non-forest land), which can be demonstrated through a qualitative assessment, opinion of local experts or literature sources. **An exception can be made if the project proponent can demonstrate that abandoned aquaculture ponds remain unused for more than 10 years.**

Location modeling (Part 3) must always be used when using the alternate population driver approach for estimation of annual areas of unplanned deforestation. Baseline rates using this approach must be reassessed every 10 years.

If using the simple historic approach to project rate of 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

If using the population driver approach to project rate of deforestation, the procedure is implemented by applying the following **three** steps:

STEP 2.1 alternate Analysis of historical deforestation and correlation to population

STEP 2.2 alternate Estimation of the annual areas of unplanned baseline deforestation in the reference region

**Estimation of annual areas of unplanned deforestation based on simple historic**

**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 substeps:

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 must 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\textsuperscript{12} with historical deforestation data.

As a minimum requirement:

- Collect medium resolution remotely sensed spatial data\textsuperscript{13} (30m x 30m resolution or less, such as Landsat, Resourcesat-1, Sentinel-2, or Spot sensor data) of 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 points in time over a maximum of 12 years must be included; however, additional points within or beyond the 12-year period may be added to enhance the deforestation trend analysis. Resolution of the spatial data must be 30 m x 30 m or less. Examples of such remote sensing instruments are, amongst others: Landsat, Resourcesat-1, Sentinel-1, Sentinel-2, JERS-1, ALOS/PALSAR, SPOT, Rapid Eye, PlanetLab.

- 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-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 versus non-forest as per Step 2.1.4. The first point in time following the project start date must be validated in situ or through a 'more reliable' remote sensing dataset. While in situ data may be more reliable, they may not be fully representative. Thus a reliable ancillary remote sensing dataset with fine resolution (e.g., 5 m resolution) may be used. These data must be of sufficient quality to produce an initial map with a forest/non-forest classification accuracy better than 90\%, as per Step 2.1.4.

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

2.1.2. Mapping of historical deforestation\textsuperscript{14}

Using the data collected in Step 2.1.1 divide the reference region (RRD) into polygons\textsuperscript{15} representing “forest” land and “non-forest” land at different dates in the past\textsuperscript{16} (Forest Cover Maps) as well as

\textsuperscript{12} This is required for Part\textsuperscript{ART} 3 - Location and quantification of the threat of unplanned baseline deforestation.

\textsuperscript{13} 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.

\textsuperscript{14} 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.

\textsuperscript{15} 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.

\textsuperscript{16} For the purpose of this module, mapping forest and non-forest land is sufficient. However, project participants may consider dividing these two classes in subclasses 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. 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.
“deforested” land (Deforestation Maps) at different time periods in the past. The latter is generated from successive Forest Cover Maps.

Deforestation Maps showing areas of deforestation with paired data (i.e., matching forest area and population data for specific dates) shall be prepared and available for the time periods between each historic image.

There is no specific method prescribed for forest land and deforestation mapping. The project proponent may select from the heterogeneity-variety of existing methods, data sources, and software. No specific methodology is prescribed for forest land and deforestation mapping. However, good practice of remote sensing analysis must be followed in any case.17 The selected mapping methods for each land cover type (i.e., 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 must come from areas that were cloud free in both dates in question. This must be estimated in hectares per year.

2.1.4. Map accuracy assessment

A verifiable accuracy assessment of the maps (AA) produced in the previous substep is necessary to produce a credible estimate of the historical deforestation rate.18

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 attains 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 ≤5 m) 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

17 For example, GOFC-GOLD (2009); Klemas, V. (2013); Kuenzer et al. (2011); Kumar & Patnaik (2013); Rundquist et al. (2001).

algorithm used for the most recent image to achieve the 98% minimum accuracy level of the map product is applicable to the past images and will achieve the same accuracy.\textsuperscript{19}

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: $A_{BSL,RRD,unplanned,t} = m^*th + int$

b. Non-linear
   i. PowerExponential: $A_{BSL,RRD,unplanned,t} = c^*th^b$
   ii. Logarithmic: $A_{BSL,RRD,unplanned,t} = c^*\ln(th) + b$

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 a linear regression projecting decreasing annual areas of deforestation is significant it must be used.

If no significant regression results, the mean area deforested, in 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:

\textsuperscript{19} 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 applicable is 3-5 years, this is a valid assumption.
Where:

\[ A_{BSL, RRD, unplanned, t} = \frac{A_{RRD, unplanned, hrp}}{T_{hrp}} \]  \hspace{1cm} (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

**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:

\[ A_{BSL, RRL, unplanned, t} = A_{BSL, RRD, unplanned, t} \times P_{RRL} \]  \hspace{1cm} (4)

Where:

- \( A_{BSL, RRL, unplanned, t} \) 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 \( A_{BSL, RRL, unplanned, t} \) 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):

\[ A_{BSL, PA, unplanned, t} = A_{BSL, RRD, unplanned, t} \times P_{PA} \]  \hspace{1cm} (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):

\[ A_{BSL, LK, unplanned, t} = A_{BSL, RRD, unplanned, t} \times P_{LK} \]  \hspace{1cm} (6)

Where:
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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

\[
A_{BSL,PA,unplanned} = \sum_{t=1}^{t^*} A_{BSL,PA,unplanned,t} \tag{7}
\]

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

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

Estimation of annual areas of unplanned deforestation based on population driver

STEP 2.1 alternate. Analysis of historical deforestation and correlation to population

For the RRD, determine the forest area that is cleared per additional person(s) entering the population, expressed as parameter \( DP \), where \( DP \) is equal to the change in deforested area (ha) coinciding with a given change in population (# of individuals).

Parameter \( DP \) can be estimated through either:

1. Participatory Rural Appraisal or other survey methods (2.1.1 alternate); or,

2. Analysis of imagery and population census data (2.1.2 alternate).

The RRD can be divided into subsets, and separate \( DP \) parameters derived for each, to improve spatial accuracy. Subsets of the RRD for which separate \( DP \) parameters \( DP_j \) are derived must be composed of contiguous census units and must be justified on the basis of criteria independent of population level and deforested area (e.g., socio-economic circumstances and/or land use practices).

2.1.1 Alternate. Estimation of parameter \( DP \) through Participatory Rural Appraisal or other survey methods

Parameter \( DP \) can be directly estimated through surveys of the RRD population using Participatory Rural Appraisal or other methods. Surveys must make use of the same population census from which
population will be projected over the baseline period (Step 2.2 alternate) as the population from which survey samples (households) are selected. Surveys must be designed to produce statistically valid results, with unbiased selection of households, e.g., ensuring that both rural and urban dwellers are surveyed in proportion to their representation in the RRD population.

Surveys must be constructed to produce the following parameters for each sampled household:

\[ D = \text{ha forest cleared by household via unplanned (unsanctioned) deforestation in past 10 years} \]
\[ P_1 = \text{number of people in the household immigrating in the past 10 years} \]
\[ P_2 = \text{number of new children born to the household since immigrating and in the past 10 years} \]

Parameter \(DP\) is then calculated for each household as

\[ DP_{i,j} = \frac{D_i}{(P_{1,i}+P_{2,i})} \]  

(9)

Where:

- \(DP_{i,j}\) Area of unplanned deforestation produced by change in population in household \(i\) subset \(j\) of the RRD; ha * # of individuals
- \(D_i\) Hectares of forest cleared by household \(i\) via unplanned (unsanctioned) deforestation in past 10 years; ha
- \(P_{1,i}\) Number of people in household \(i\) immigrating in the past 10 years; # of individuals
- \(P_{2,i}\) Number of new children born to household \(i\) since immigrating and in the past 10 years; # of individuals
- \(i\) 1, 2, 3, …\(M\) sampled households
- \(j\) 1, 2, 3, …\(N\) subsets of RRD (sets of census units with separate \(DP\) parameters)

If there is no land cleared to accommodate a growing population (e.g., a settled, more urbanized population), parameter \(DP\) is assumed to be zero (i.e., growing population does not require an increasing proximal land base to support it).

2.1.2 Alternate. Estimation of parameter \(DP\) through analysis of imagery and population census data

Alternately, \(DP\) may be indirectly estimated through analysis pairing historic imagery and population census data for 2 or more points in time in the period 20 years prior to project start. In this step, \(DP\) is calculated as the correlation between observed changes in (dynamic analysis) or levels of (static analysis) deforested area and population in the RRD.

The following steps will be carried out:

Step 2.1.2.1 alternate. Collection and processing of appropriate data sources
Step 2.1.2.2 alternate. Dynamic analysis of population and deforestation
Step 2.1.2.3 alternate. Static analysis of population and deforestation *(if results inconclusive with dynamic analysis)*

**2.1.2.1 Alternate. Collection and processing of appropriate data sources**

Maps of deforested areas in the RRD will be produced for 2 or more points in time in a period no more than 20 years prior to project start (or prior to subsequent date when baseline is revised). The remote sensing data and its interpretation, from which the maps are produced, shall meet the same requirements as those described in Sections 2.1.1 to 2.1.4.

Population census data corresponding to the dates of the imagery will be collected. Where imagery and census data cannot be obtained for the same year(s), population estimates may be interpolated between census events and/or extrapolated from the latest census event to coincide with imagery dates. Official population data will be used preferentially, and where they are not available, population estimates may be sourced from independent representative surveys. In particular, census data must have equally accurate representation of both urban and rural populations. Census techniques must apply general good practice as outlined in the United Nations 2007 publication of Principles and Recommendations for Population and Housing Censuses, Revision 2.

**Step 2.1.2.2 alternate. Dynamic analysis of correlation between population and deforestation**

For the interval(s) between the imagery/census dates, for each population census unit, the following will be calculated:

1. Change (Δ) in deforested land area (in hectares) (as per procedures described in Sections 2.1.2 and 2.1.3) = dependent variable
2. Δ population (# of individuals) = independent variable

A regression model will be constructed to assess the relationship between the two above variables across the population census units, where

\[
\Delta \text{ deforested area (ha)} = f(\Delta \text{ population (# of individuals)}).
\]

If model results are statistically significant (\(p < 0.05\)) and unbiased (i.e., minimal trend in residuals), with an adjusted R-squared \(\geq 0.50\), the model will be used to produce parameter \(DP\) for application in Step 2.2.2 alternate. It must further be demonstrated that the resulting \(DP\) parameter does not represent a spurious correlation between population and deforestation, substantiated through a qualitative assessment, opinion of local experts or literature sources. If model results do not meet these criteria, proceed to Step 2.1.2.3 alternate below.

**Step 2.1.2.3 alternate. Static analysis of correlation between population and deforestation**

A static analysis, from which \(DP\) is inferred from correlation of current population and deforested area (representing past changes in population and deforested area), may be used if results of the dynamic analysis are inconclusive and the following applicability conditions are met:

1. RRD was predominately forested prior to settlement (i.e., non-forest areas were forested historically)

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20 Available at http://unstats.un.org/unsd/demographic/sources/census/docs/P&R_%20Rev2.pdf
2. Typically, new settlers clear land within 5 years from arrival (to permit employing the simplifying assumption that deforestation occurs simultaneously with population growth)

3. Agents of deforestation employed similar land-use practices throughout the historic reference period as are expected in the project area during the project term (note that for this model, the relevant historic period predates the earliest data point, i.e., extends back to original settlement).

The above applicability conditions can be demonstrated through a qualitative assessment, opinion of local experts or literature sources. The static analysis can only be used to estimate $DP$ for baseline projections for the first 10 years from project start; baseline revisions after the first 10 years must use either the Participatory Rural Appraisal or other survey method (Step 2.1.1 alternate) or the dynamic analysis (Step 2.1.2.2 alternate) to estimate $DP$.

Using the same population census units in Step 2.1.2.2 above, calculate the following for each population census unit for the most recent imagery/census date:

1. Deforested land area (in hectares) (as per procedures described in Sections 2.1.2 alternate and 2.1.3 alternate) = dependent variable
2. Population (# of individuals) = independent variable

A linear regression model will be constructed to assess the relationship between the two above variables across the population census units, where

$$\text{deforested area (ha)} = f(\text{population (# of individuals)})$$

If model results are statistically significant ($p < 0.05$) and unbiased (i.e., minimal trend in residuals), with an adjusted R-squared $\geq 0.50$, the model slope parameter will be used as parameter $DP$ for application in Step 2.2.2 alternate. It must further be demonstrated that the resulting $DP$ parameter does not represent a spurious correlation between population and deforestation, substantiated through a qualitative assessment, opinion of local experts or literature sources. If model results do not meet these criteria, parameter $DP$ is assumed to be zero.

**STEP 2.2 alternate. Estimation of the annual areas of unplanned baseline deforestation in the reference region**

To estimate the annual areas of unplanned baseline deforestation in the RRD, the following steps will be carried out.

**Step 2.2.1 alternate. Project population in the RRD**

Population in each census unit of the RRD will be projected using the most recent census date as the starting point. Official population projections will be used preferentially. Where not provided at the scale of individual population census units composing the RRD, higher-level official population projections (e.g., national) can be distributed among population census units in proportion to population correlates/indicators (e.g., school matriculations, households).

Where official population projections are not available, population growth rate shall be calculated from population data from 2 or more census dates in a period not exceeding 20 years prior to the project start date (collected in Step 2.1.2.1 alternate above).
Prior to calculating population growth rate (below), the absence of any factors that could significantly reduce population growth in the RRD over the term of projection relative to the historic period (e.g., policy changes, war, disease, famine) must be confirmed through a qualitative assessment, opinion of local experts or literature sources. In the event that presence of significant factors is confirmed, census units within which those factors are operating will be identified and assumed to have zero population growth during the projection period.

Population growth rate shall be calculated using either

1. Linear model (constant rate) if only 2 census dates are available in the period or it cannot be demonstrated that population growth rate increased over 2 or more intervals within the period; or,

2. Exponential model if 3 or more census dates are available in the period and it can be demonstrated that population growth rate increased over 2 or more intervals within the period.

When using the linear model, population for each census unit $i$ is projected as:

$$P_{pop_i,t^*} = P_{pop_i,t_2} + \frac{P_{pop_i,t_2} - P_{pop_i,t_1}}{t_2-t_1} \times (t^* - t_2)$$  \hspace{1cm} (10)

Where:

- $P_{pop_i,t^*}$: Projected population in census unit $i$ in year $t^*$; # of individuals
- $P_{pop_i,t_2}$: Population in census unit $i$ at $t_2$ (most recent census date preceding project start date); # of individuals
- $P_{pop_i,t_1}$: Population in census unit $i$ at $t_1$; # of individuals
- $i$: 1, 2, 3, … $M$, population census units
- $t$: 1, 2, 3, … $t$ years elapsed since the projected start of the REDD project activity

When using the exponential model, population for each census unit $i$ is projected as:

$$P_{pop_i,t^*} = P_{pop_i,t_2} \times \left(\frac{P_{pop_i,t_2}}{P_{pop_i,t_1}}\right)^{\frac{t^* - t_1}{t_2 - t_1}}$$ \hspace{1cm} (11)

Where:

- $P_{pop_i,t^*}$: Projected population in census unit $i$ in year $t^*$; # of individuals
- $P_{pop_i,t_2}$: Population in census unit $i$ at $t_2$ (most recent census date preceding project start date); # of individuals
- $P_{pop_i,t_1}$: Population in census unit $i$ at $t_1$; # of individuals
- $i$: 1, 2, 3, … $M$, population census units
- $t$: 1, 2, 3, … $t$ years elapsed since the projected start of the REDD project activity
Step 2.2.2 Alternate. Project deforestation in the RRL and project area as a function of population

As the first step to projecting unplanned baseline deforestation in the RRL, deforestation for each census unit is projected as:

\[ A_{BSL,i,unplanned,t} = (Pop_{i,t} - Pop_{i,t-1}) * DP_j \]  

(12)

Where:

- \( A_{BSL,i,unplanned,t} \) Projected area of unplanned baseline deforestation in census unit \( i \) member of RRD subset \( j \) in year \( t \); ha
- \( Pop_{i,t} \) Projected population in census unit \( i \) in year \( t \); # of individuals
- \( Pop_{i,t-1} \) Projected population in census unit \( i \) at \( t-1 \); # of individuals
- \( DP \) Area of unplanned deforestation produced by change in population in subset \( j \) of the RRD; ha * # of individuals
- \( i \) 1, 2, 3, … \( M \) population census units
- \( j \) 1, 2, 3, … \( N \) subsets of RRD (sets of census units with separate DP parameters)
- \( t \) 1, 2, 3, … \( t \) years elapsed since the projected start of the REDD project activity

Note that if the term \((Pop_t - Pop_{t-1})\) in Equation 12 above is \(<0\), the value of \( A_{BSL,unplanned,t} \) is assigned as zero. If the term \( Pop_t \) in Equation 12 exceeds the highest population value from the dataset from which \( DP \) was derived using the static model, the value of \( A_{BSL,unplanned,t} \) is assigned as zero. If the term \((Pop_t - Pop_{t-1})\) in Equation 12 exceeds the highest population change value from the dataset from which \( DP \) was derived using the dynamic model, the value of \( A_{BSL,unplanned,t} \) will be set as the corresponding deforested land area for the highest population change value from the dataset.

Prior to application of projected deforestation to the RRL (3.4.2), census units may be consolidated into larger subsets of the RRL, \( RRL_i \), to allow deforestation pressure to be exerted beyond the limits of a population’s census unit. Subsets of the RRL may be constructed progressively by consolidating adjoining census units that are linked by existing or planned transportation routes (e.g., roads, navigable rivers). The RRL may thus be a single unit or composed of multiple (up to the number of component census units) subsets to which deforestation projections are applied. Subsets of the RRL need not coincide with subsets of the RRD.

The projected unplanned baseline deforestation in the reference region is estimated as follows:

\[ A_{BSL,RRD,unplanned,t} = \sum_{j}^{N} \sum_{i}^{M} A_{BSL,i,unplanned,j,t} \]  

(13)

Where:

- \( A_{BSL,RRD,unplanned,t} \) Projected area of unplanned baseline deforestation in the reference region in year \( t \); ha

Note that in conformance with VCS AFOLU Guidance Section 4.4.8, where RRL subsets are justified on the basis of “…infrastructure (e.g., roads) that does not yet exist”, clear evidence be provided to demonstrate that such infrastructure would have been developed in the baseline scenario. Evidence may include permits, maps showing construction plans, construction contracts or open tenders, an approved budget and/or evidence that construction has started.
**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\(^{22}\) 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 \( \geq 25\% \) of the project geographic boundary (excluding water bodies) is within 50 m 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.

A location analysis is always required when using the population driver approach for projecting rate of deforestation.

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\(^{22}\) 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).
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. The model/software used must:

- Be peer-reviewed
- Be transparent (no black box calculations).
- 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

To be transparent, the modeling system must provide feedback on the relative contribution of explanatory variables and assess model fit through comparisons with empirical data. Further, in applying the model/software, project proponents must provide clear documentation and justification for all model inputs and assumptions.

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

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**: Where relevant, vegetation type, soil fertility, slope, elevation, hydrology, sedimentation and salinity rate of SLR related to sediment deposition.
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, distance to ports, 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 land).

---

23 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.
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 VCS).

**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.

When using Artificial Neural Networks to determine the model that best fits (has lowest error), project proponents will apply the following guidance:

1. For the calibration period (i.e., the first time step in the historical reference period, used to calibrate the model), a minimum of 5,000 samples (pixels) of the “transition” category (forest to non-forest) and 5,000 samples (pixels) of the “persistence” category (locations that do not transition but remain as forest) will be randomly selected and used for training and testing.

2. A minimum of 10,000 iterations of the model will be run before selecting the model that best fits.

The map with the best fit will be the map that best reproduces 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). 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.

\[
FOM = \frac{\text{CORRECT}}{\text{CORRECT} + \text{Err}_A + \text{Err}_B}
\]  

(15)

Where,
- \( \text{CORRECT} \): Area correct due to observed change predicted as change; ha
- \( \text{Err}_A \): Area of error due to observed change predicted as persistence; ha
- \( \text{Err}_B \): Area of error due to observed persistence predicted as change; ha

The minimum threshold for the best fit as measured by the \( FOM \) shall be defined by the net observed change in the reference region for the calibration period of the model. Net observed change shall be calculated as the total area of change being modeled in reference region during the calibration period as percentage of the total area of the reference region. The \( FOM \) value shall be at least equivalent to this value. If the \( FOM \) value is below this threshold, project proponents must provide evidence that the \( FOM \) achieved is consistent with comparable studies given the nature of the project area and the data available.

**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 (in all relevant carbon pools).

- Perform a separate assessment for terrestrial and wetland strata,\(^{25}\) if applicable.
- 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 \( A_{\text{BSL,PA,unplanned},t} \) for the project area and \( A_{\text{BSL,LK,unplanned},t} \) for the leakage belt.

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

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

---

\(^{25}\) Different drivers and deforestation rates may apply to terrestrial and wetland forests
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.

When using the population driver approach for projecting rate of deforestation, the RRL may be disaggregated into discrete subsets to which deforestation projections are applied, and thus the steps below would be carried out independently for each $RRL_j$ subset. Also, when using the population driver approach for projecting rate of deforestation, it should be noted that portions of the project area that are outside of the RRL (i.e., in cases where the RRD and RRL do not cover the entire project area) are not allocated (and assumed not subject) to deforestation.

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 in the 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.
- Compile all yearly (or periodical) baseline deforestation maps into one single map, showing the expected Baseline Deforestation for the Baseline Period and, optionally, Project Duration.
- Prepare a table showing the number of hectares in the project area that will be deforested each year in the baseline case for the baseline period. 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 into 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)

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 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 Module CP-AB).

Use the methods described in the carbon pool modules (CP-AB, CP-D, CP-L and CP-S) to determine the carbon stock of each forest stratum. When applying Module BL-UP for AUWD project activities, disregard the above reference to Module CP-S and use Module BL-TW instead for soil carbon accounting.

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 given cyclical post-deforestation land-use systems such as shifting agriculture with fallow). These stocks depend on the assumed land uses after deforestation in each post-deforestation land-uses.

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. A 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.
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., see 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. 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. 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.

4.2.3 Estimation of carbon stock changes per stratum

Stock changes in each pool are calculated by subtracting post-deforestation carbon stocks from forest carbon stocks.

\[
\Delta C_{AB\text{-tree},i} = C_{AB\text{-tree,bsl},i} - C_{AB\text{-tree,post},i} \\
\Delta C_{AB\text{-non-tree},i} = C_{AB\text{-non-tree,bsl},i} - C_{AB\text{-non-tree,post},i} \\
\Delta C_{BB\text{-tree},i} = C_{BB\text{-tree,bsl},i} - C_{BB\text{-tree,post},i} \\
\Delta C_{BB\text{-non-tree},i} = C_{BB\text{-non-tree,bsl},i} - C_{BB\text{-non-tree,post},i} \\
\Delta C_{DW,i} = C_{DW,bsl,i} - C_{DW,post,i} \\
\Delta C_{LI,i} = C_{LI,bsl,i} - C_{LI,post,i} \\
\Delta C_{SOC,i} = C_{SOC,bsl,i} - C_{SOC,PD-BSL,i} 
\]

Where:

- \( \Delta C_{AB\text{-tree},i} \): Baseline carbon stock change in aboveground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( C_{AB\text{-tree,bsl},i} \): Forest carbon stock in aboveground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( C_{AB\text{-tree,post},i} \): Post-deforestation carbon stock in aboveground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( \Delta C_{BB\text{-tree},i} \): Baseline carbon stock change in belowground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( C_{BB\text{-tree,bsl},i} \): Forest carbon stock in belowground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( C_{BB\text{-tree,post},i} \): Post-deforestation carbon stock in belowground tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( \Delta C_{AB\text{-non-tree},i} \): Baseline carbon stock change in aboveground non-tree biomass in stratum \( i \); t CO₂e ha\(^{-1}\)
- \( C_{AB\text{-non-tree,bsl},i} \): Forest carbon stock in aboveground non-tree vegetation in stratum \( i \); t CO₂e ha\(^{-1}\)

\(^{26}\) 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.
\[ C_{AB\text{-non-tree, post},i} \text{ Post-deforestation carbon stock in aboveground non-tree vegetation in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ \Delta C_{BB\text{-non-tree},i} \text{ Baseline carbon stock change in belowground non-tree biomass in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{BB\text{-nontree,bl},i} \text{ Forest carbon stock in belowground non-tree biomass in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ \Delta C_{BB\text{-nontree,post},i} \text{ Post-deforestation carbon stock in belowground non-tree biomass in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ \Delta C_{DW,i} \text{ Baseline carbon stock change in dead wood in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{DW,bl,i} \text{ Forest carbon stock in dead wood in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{DW,post,i} \text{ Post-deforestation carbon stock in dead wood in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ \Delta C_{LI,i} \text{ Baseline carbon stock change in litter in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{LI,bl,i} \text{ Forest carbon stock in litter in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{LI,post,i} \text{ Post-deforestation carbon stock in litter in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ \Delta C_{SOC,i} \text{ Baseline carbon stock change in soil organic carbon in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{SOC,bl,i} \text{ Forest carbon stock in soil organic carbon in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ C_{SOC,PD-BSLi} \text{ Post-deforestation carbon stock in soil organic carbon in stratum } i; \text{ t CO}_2\text{e ha}^{-1} \]

\[ i \] Number of strata \( i = 1, 2, 3, \ldots \)

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

In the situation where the baseline includes harvesting of long-lived wood products, the harvested wood products carbon pool (Module CP-W) shall be included. For calculation of carbon stock sequestered in wood products, see Module CP-W.

Stock changes in aboveground biomass and litter are emitted at the time of deforestation. Following deforestation, emissions from belowground biomass, dead wood, soil and wood products take place gradually over time. Stock changes in belowground biomass and dead wood are emitted at an annual rate of 1/10 of the stock change for 10 years and at an annual rate of 1/20 of the stock change for 20 years for soil organic carbon. Carbon stocks entering the wood products pool at the time of deforestation and that are expected to be emitted over 100 years are emitted at an annual rate of 1/20 of the stock for 20 years. Thus, for a given year \( t \), emissions are summed across areas deforested from time \( t-10 \) up to time \( t \) (for belowground biomass and dead wood) and from time \( t-20 \) up to time \( t \) (for soil organic carbon and wood products), in the equation below:

\[
\Delta C_{TOT} = \sum_{t=1}^{i} \sum_{l=1}^{h} \Delta C_{BSL,lt} \tag{23}
\]

\[
\Delta C_{BSL,lt} = A_{unplanned,lt} \cdot (\Delta C_{ABtree,lt} + \Delta C_{AB\text{-non-tree},lt} + \Delta C_{LI,lt}) + \left( \sum_{t=10}^{i} A_{unplanned,lt} \cdot (\Delta C_{BBtree,lt} + \Delta C_{BB\text{-non-tree},lt} + \Delta C_{DW,lt}) \cdot \left( \frac{1}{10} \right) + \left( \sum_{t=20}^{i} A_{unplanned,lt} \cdot (C_{WP100,lt} + \Delta C_{SOC,lt}) \cdot \left( \frac{1}{20} \right) \right) \right) \tag{24}
\]
Where:

\[ \Delta C_{TOT} \] Sum of the baseline carbon stock change in all pools up to time-year \( t^* \); t CO\textsubscript{2}e (calculated separately for the project area [PA] and the leakage belt [LB])

\[ \Delta C_{BSL,i,t} \] Sum of the baseline carbon stock change in all pools in stratum \( i \) at time \( t \); t CO\textsubscript{2}e

\[ A_{unplanned,i,t} \] Area of unplanned deforestation in forest stratum \( i \) at time \( t \); ha

\[ C_{WP100,i} \] Carbon stock entering the wood products pool at the time of deforestation that is expected to be emitted over 100 years from stratum \( i \); t CO\textsubscript{2}e

\[ \Delta C_{AB\text{-}tree,i} \] Baseline carbon stock change in aboveground tree biomass in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{BB\text{-}tree,i} \] Baseline carbon stock change in belowground tree biomass in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{AB\text{-}non\text{-}tree,i} \] Baseline carbon stock change in aboveground non-tree biomass in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{BB\text{-}non\text{-}tree,i} \] Baseline carbon stock change in belowground non-tree biomass in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{DW,i} \] Baseline carbon stock change in dead wood in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{LI,i} \] Baseline carbon stock change in litter in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\[ \Delta C_{SOC,i} \] Baseline carbon stock change in soil organic carbon in stratum \( i \); t CO\textsubscript{2}e ha\textsuperscript{-1}

\( i = 1, 2, 3, \ldots M \) strata

\( t = 1, 2, 3, \ldots t^* \) years elapsed since the projected start of the REDD project activity

**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:

\[
GHG_{BSL,E} = \sum_{i=1}^{M} \sum_{t=1}^{t^*} (E_{FC,i,t} + E_{BiomassBurn,i,t} + N_2O_{direct-N,i,t})
\]  

Where:

\[ GHG_{BSL,E} \] Greenhouse gas emissions as a result of deforestation activities within the project boundary in the baseline; t CO\textsubscript{2}e

\[ E_{FC,i,t} \] CO\textsubscript{2} emission from fossil fuel combustion in stratum \( i \) in year \( t \); t CO\textsubscript{2}e

\[ E_{BiomassBurn,i,t} \] Non-CO\textsubscript{2} emissions due to biomass burning as part of deforestation activities in stratum \( i \) in year \( t \); t CO\textsubscript{2}e

\[ N_2O_{direct-N,i,t} \] Direct N\textsubscript{2}O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum \( i \) in year \( t \); t CO\textsubscript{2}e

\( t = 1, 2, 3, \ldots t^* \) 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 Modules E-FFC, E-B\textsubscript{PB} and E-NA\textsuperscript{27}.

\[ ^{27} \text{http://cdm.unfccc.int/EB/033/eb33_repan16.pdf} \]
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**

\[
\Delta C_{BSL,unplanned} = \Delta C_{BSL,PA,unplanned} + GHG_{BSL,E} 
\]

\[
\Delta C_{BSL,PA,unplanned} = \Delta C_{TOT,PA} 
\]

\[
\Delta C_{BSL,LK,unplanned} = \Delta C_{TOT,LB} 
\]

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\_year \( t^* \) 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\_year \( t^* \) in the leakage belt; t CO\(_2\)e

### 6 PARAMETERS

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<td>Number of individuals per population census unit ( i ) in year ( t )</td>
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<td>Used in equations:</td>
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<td>Source of data:</td>
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<td>Monitoring frequency:</td>
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<tr>
<td>QA/QC procedures:</td>
<td>Census data must have equally accurate representation of both rural and urban populations. Census techniques must apply general good practice as outlined in United Nations 2007. Principles and Recommendations for Population and Housing Censuses. Revision 2(^{28})</td>
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\(^{28}\) Available at http://unstats.un.org/unsd/demographic/sources/census/docs/P&R_%20Rev2.pdf
### Data / parameter: \( DP_j \)
- **Data unit:** ha \( \times \) # of individuals
- **Used in equations:** 12
- **Description:** Area of unplanned deforestation in year \( t \) produced by change in population in the interval \( t-1 \) to \( t \) for subset of RRD \( j \)
- **Source of data:** Representative surveys or analysis of imagery and population data
- **Measurement procedures (if any):**
- **Monitoring frequency:** Must be updated every 10 years
- **QA/QC procedures:**
- **Any comment:**

### Data / parameter: \( D_i \)
- **Data unit:** ha
- **Used in equations:** 9
- **Description:** ha forest cleared by household \( i \) in past 10 years
- **Source of data:** Representative surveys
- **Measurement procedures (if any):**
- **Monitoring frequency:** Must be updated every 10 years
- **QA/QC procedures:**
- **Any comment:**

### Data / parameter: \( P_{1,i} \)
- **Data unit:** # of individuals
- **Used in equations:** 9
- **Description:** number of people in household \( i \) immigrating in the past 10 years
- **Source of data:** Representative surveys
- **Measurement procedures (if any):**
- **Monitoring frequency:** Must be updated every 10 years
- **QA/QC procedures:**
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<td>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).</td>
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<td>Maps showing the location of deforested hectares in each year of the baseline period</td>
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<td>Description:</td>
<td>Leakage belt area</td>
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<td>Source of data:</td>
<td>GPS coordinates and/or remote sensing data</td>
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<td>Measurement procedures (if any):</td>
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<td>Monitoring frequency:</td>
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<td>QA/QC procedures:</td>
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<tr>
<td>Any comment:</td>
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### 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. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.

**Monitoring frequency**: Must be updated each time the baseline is revisited (at least every 10 years)

**QA/QC procedures**: Any measurement procedures (if any)

**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**: 14
- **Description**: The area of RRL suitable for conversion from forest to an alternate land use
- **Source of data**: 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 Module M-MONREDD

**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**: 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**

**Any comment**: 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 1 km, shall be visited. If a
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.

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<td>( P_{LK} )</td>
<td>Ratio of the area of the leakage belt to the total area of RRD</td>
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<td>Any comment:</td>
<td>Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for <em>ex-ante</em> purposes</td>
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<td>Ratio of forest area in the <a href="#">RRL</a> at the start of the historical reference period to the total area of the RRD</td>
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<td>Description:</td>
<td>Geographic boundaries of the reference area for projection of rate of deforestation</td>
</tr>
<tr>
<td>Source of data:</td>
<td>GPS coordinates and/or remote sensing data</td>
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<td>( T_{hrp} )</td>
<td>Geographic boundaries of the reference area for projection of location of deforestation</td>
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<td>( A_{RRD, unplanned,hrp} )</td>
<td>Total area deforested during the historical reference period in RRD</td>
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<td>( A_{RRL, forest,t} )</td>
<td>Remaining area of forest in RRL at time ( t )</td>
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**Data unit:**
- \( T_{hrp} \): Yr
- \( A_{RRD, unplanned,hrp} \): Ha
- \( A_{RRL, forest,t} \): Ha

**Measurement procedures (if any):**
- Must be updated each time the baseline is revisited (at least every 10 years)

**Quality Assurance / Quality Control:**
- Must be between 10 and 15 years

**Module parameter originates in:**
- Module M-MONREDD
- Module M-REDD-MON
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<tr>
<td>Description:</td>
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<td>Used in equations:</td>
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<tr>
<td>Description:</td>
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</tr>
<tr>
<td>Module parameter originates in:</td>
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<td>Mean post-deforestation stock in soil organic carbon in the post deforestation stratum $i$</td>
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<td>Mean carbon stock in wood products pool (stock remaining in wood products after 100 years) from stratum $i$</td>
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<td>Data / parameter</td>
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<td>$E_{\text{BiomassBurn},i,t}$</td>
<td>Non-$\text{CO}_2$ emissions due to biomass burning as part of degradation activities in stratum $i$ in year $t$</td>
</tr>
<tr>
<td>$E_{\text{FC},i,t}$</td>
<td>$\text{CO}_2$ emission from fossil fuel combustion in stratum $i$ in year $t$</td>
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<td>$N_2\text{O}_{\text{direct-N},i,t}$</td>
<td>Direct $N_2\text{O}$ emission as a result of nitrogen application on the alternative land use within the project boundary in stratum $i$ in year $t$</td>
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**Data / parameter:** Regional Forest Cover / Non-Forest Cover Benchmark Map

**Data / parameter:** Project Forest Cover Benchmark Map
| 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: | Module M-REDD-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: | Module M-REDD-MON |
| Any comment: | |
7 REFERENCES AND OTHER INFORMATION

References


Exhibit 1. Illustrative RRD, RRL, leakage belt and project area boundaries for the population driver approach

Note: Bold dashed line = project area; bold solid line = boundary of RRD and RRL; gray areas = leakage belt (forest cover at project start); light lines = boundaries of census units composing the RRD
## DOCUMENT HISTORY

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Comment</th>
</tr>
</thead>
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<tr>
<td>v1.0</td>
<td>3 Dec 2010</td>
<td>Initial version released</td>
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<tr>
<td>v2.0</td>
<td>7 Sept 2011</td>
<td>The module was revised to include an alternative approach to determining the baseline scenario based on an observed relationship between population and deforestation (called population driver approach). The population driver approach adds alternative steps to the existing historic approach throughout the module. This module was revised by The Field Museum, which was prepared by TerraCarbon. The module was also updated to limit the reassessment of the unplanned baseline scenario to every ten years.</td>
</tr>
<tr>
<td>v3.0</td>
<td>19 July 2012</td>
<td>The module was updated to revise the procedure for calculating uncertainty for the population driver parameter. In addition, the revision addressed the types of acceptable models for spatial modeling and provides a new threshold for the figure of merit. This module was revised by The Field Museum and was prepared by TerraCarbon.</td>
</tr>
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| v3.1    | 20 Nov 2012| The module was revised to account for a decay of carbon from the belowground biomass, dead wood, soil carbon and harvested wood products pools and the following revisions were made:  
  - Equations 16 to 22 account for the carbon stock change in each pool separately  
  - In equations 23 and 24, the carbon stock is emitted annually over 10 years for belowground biomass and dead wood and emitted annually over 20 years for soil carbon and the harvested wood products portion that will be emitted before year 100. |
| v3.2    | 3 May 2013 | The module was revised to remove the applicability condition, “it shall be demonstrated that post-deforestation land use shall not constitute reforestation”                                                     |