VCS MODULE VMD0007

REDD METHODOLOGICAL MODULE:

ESTIMATION OF BASELINE CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSIONS FROM UNPLANNED DEFORESTATION (BL-UP)

Version 3.1

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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.

2 SUMMARY DESCRIPTION OF THE MODULE

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

3 DEFINITIONS AND ACRONYMS

Definitions

The following definitions are provided to assist the reader. 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Calibration period - The first time step in the historical reference period, used to calibrate the model

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 *l*, the risk, or "suitability", for deforestation as a numerical scale

Transition deforestation - Transition configurations are any landscape that do not meet the definition of mosaic or frontier

[1] **Avoiding Unplanned Deforestation and Degradation (AUDD)** reduces net GHG emissions by stopping deforestation and/or degradation of degraded to mature forests that have been expanding historically or will expand in the future, in a frontier, mosaic or transition configuration.

a. Frontier configurations are described as any landscape in which none of the forest in the project area has current direct physical connection with areas anthropogenically deforested.
b. Mosaic configurations are described as any landscape in which no patch of forest in the project area exceeds 1000 ha and the forest patches are surrounded by anthropogenically cleared land
c. Transition configurations are any landscape that do not meet the definition of mosaic or frontier.

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.

AUDD – Avoiding Unplanned Deforestation and Degradation

DEM - Digital Elevation Model

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

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

PA - Unplanned deforestation project area

RAF - Reference Area Factor

VCU – Verified Carbon Unit

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, where such clearing for crop production or ranching does not amount to large scale industrial agriculture activities[2]; (ii) have no documented and uncontested legal right to deforest the land for these purposes; and (iii) are either resident in the region (reference region—cf. section 1 below) or immigrants.
- It shall be demonstrated that post-deforestation land use shall not constitute reforestation.
- Where, pre-project, unsustainable fuelwood collection is occurring within the project boundaries modules BL-DFW and LK-DFW shall be used to determine potential leakage[3].

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[2] Small-scale / Large-scale agriculture 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

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.

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 allows the unambiguous identification of boundaries must be available.

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c. Any national or regional forestry and nature conservation regulations are complied with.

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

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

	Baseline rate approach	**Mandatory?**	**Forested %**	**Area Limitations**
Project area		Yes	100% at start of project	-
Leakage belt	Simple historic	No see LK-ASU	100% at start of project	≥90% of project (except see 1.1.3)
	Population driver	Yes	100% at start of project	None. Leakage belt is all forested area at the project start within the RRD and outside the project area (see 1.1.3 alternate)
RRD – reference area rate	Simple historic	Yes	100% at start of historical reference period	≥*MREF* (see 1.1.1.1) May not contain project area or leakage belt
	Population driver	Yes	N/A	No area limitation
RRL – reference area location	Simple historic	No see Step 3.0.	≥50% at start of project	Forested proportion must = *RRD* ± 25% at the start of project. Must contain project area and leakage belt
	Population driver	Yes	N/A	The RRL boundary is equivalent to the RRD boundary.

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*).[4]

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

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

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

The area of the *RRD* shall be calculated as follows[5]:

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

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

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

Where:

MREF	Minimum size of reference region for projecting rate of deforestation; ha
PA	Unplanned deforestation project area; ha
RAF	Reference Area Factor. Factor to multiply project area by 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 ±20% in the reference region as in the project area,
    - Rapid assessment techniques for determination of lack of legal rights to use land is the same in the reference region as in the project area, and

[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 Strategies for Climate Change, 12:1001-1026), from practical experience with pilot projects, and from expert opinion.

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

- Rapid assessment techniques for determination of proportion of agents resident in the local area (lived in area > 5yr) versus immigrants (lived in area < 5yr) is the same ±20% in the reference region as in the project area.

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

- Forest classes[7] must be present in the project area in the same proportion as in the *RRD* (±20%) at the start of the historical reference period.
- Soil types that are suitable for the land-use practice used by the main agent(s) of deforestation must be present in the project area in the same proportion as in the *RRD* (±20%).
- The ratio of slope classes "gentle" (slope <15%) to "steep" (slope ≥15%) in the project area shall be the same as the ratio in the *RRD* (±20%).
- Elevation classes (500m classes) in the project area shall be in the same proportion as in the *RRD* (±20%).

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

The following conditions shall be met:

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

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

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

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

f. **Exclusion of planned deforestation**. Areas of planned deforestation shall be excluded from the reference region boundaries where evident[8].

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

1.1.1.1 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 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 RRD from edge of project area.

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 with respect to the forested landscape, including context *outside* the RRD; or,

c. Other appropriate regional socioeconomic factors.

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

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%).

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[8] e.g. mining concessions, industrial agriculturalists, large-scale public works

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

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

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

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

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

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

1.1.3 Leakage Belt

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

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

The leakage belt must conform with the following criteria.

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

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

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

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

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

e. Transportation factors - The following conditions shall be met:

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

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

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

Minimum leakage belt area:

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

Forest Area Meeting Criteria a – g (Relative to Project Area)	Relaxation of Similarity Requirements in Criteria d and e	Leakage Belt Area
≥ 90%	None (±20% is used)	≥ 90% of the project area
≥75% - 89%	None (±20% is used)	Available forest area meeting

		criteria a – g
< 75%	Relaxation from: ±20% to ±50%	Available forest area meeting criteria a – g (with similarity requirements in d and e relaxed to ±50%)

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**[9]. 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 shall at a minimum be defined by the years between the two census data points and for location shall 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 out-rule 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;

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

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

non-forest land) which can be demonstrated through a qualitative assessment, opinion of local experts or literature sources.

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 sub-steps:

2.1.1 Collection of appropriate data sources

2.1.2 Mapping of historical deforestation

2.1.3 Calculation of the historical deforestation rate

2.1.4 Map accuracy assessment

2.1.1 Collection of appropriate data sources

Collect the data that will be used to analyze deforestation during the historical reference period within the *RRD*. This 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[10] with historical deforestation data.

As a minimum requirement:

- Collect medium resolution remotely sensed spatial data[11] (30m x 30m resolution or less, such as Landsat, Resourcesat-1 or Spot sensor data) for three points in time of no less than 3 years apart

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

covering no more than 12 years (with the first point in time being no more than 2 years from the project start date). Three time points over a maximum of 12 years must be included, however, additional points either within or beyond the 12 year period may be added to enhance the deforestation analysis.

- For the first point in time from the project start date, collect high-resolution data from remote sensors (<5 x 5 m pixels) and/or from direct field observations for ground-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.

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[12]

Using the data collected in Step 2.1.1 divide the reference region (*RRD*) into polygons[13] representing "forest" land and "non-forest" land at different dates in the past[14] (*Forest Cover Maps*) as well as "deforested" land (*Deforestation Maps*) at different time periods in the past. Deforestation Maps showing areas of deforestation with paired data shall be prepared and available for the time periods between each historic image.

Given the heterogeneity of methods, data sources, and software, no specific methodology is prescribed for forest land and deforestation mapping. However, good practice of remote sensing analysis has to be followed in any case[15]. Mapping methods for each map type (forest / deforestation) have to be able to generate consistent datasets.

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

2.1.3 Calculation of the historical deforestation

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

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[11] 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.

[12] 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.

[13] 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.

[14] 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

[15] For example, Sourcebook on REDD (GOFC-GOLD 2009).

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_U) produced in the previous sub-step is necessary to produce a credible estimate of the historical deforestation rate[16].

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

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

Where interpretation of historical remote sensing products is included in this step, it may not be possible to perform an accuracy assessment of the past image(s). If field data, aerial photographs or high resolution imagery (resolution ≤ 5m) are available for the applicable time period these shall be used. If no field data, aerial photographs or high resolution images exist it is assumed that the classification algorithm used for the most recent image to achieve the 80% or more accuracy of the map product is applicable to the past images and will achieve the same accuracy.[17]

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

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

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

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

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

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

b. Non-linear

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

[17] 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.

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

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

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

Where regression analysis is insignificant:

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

Where:

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

When applied to the project:

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

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

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

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

Where:

$A_{BSL,RR,unplanned,t}$	Projected area of unplanned baseline deforestation in the reference region for location (*RRL*) in year *t;* ha

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

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

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

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

Where:

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

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

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

Where:

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

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

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

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 use the same population censused (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 = ha forest cleared by household via unplanned (unsanctioned) deforestation in past 10 years

P_1 = number of people in the household immigrating in the past 10 years

P_2 = 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

$$DP_{i,j} = \frac{D_i}{(P_{1,i}+P_{2,i})} \qquad (9)$$

Where:

$DP_{i,j}$	Area of unplanned deforestation produced by change in population in household *i* subset *j* of the RRD; ha * # of individuals^{-1}
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[18].

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:

[18] Available at http://unstats.un.org/unsd/demographic/sources/census/docs/P&R_%20Rev2.pdf

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

Δ deforested area (ha) = ƒ(Δ population (# of individuals)).

If model results are statistically significant ($p \leq 0.05$) and unbiased (i.e. minimal trend in residuals), with an adjusted R-squared ≥ 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)
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

deforested area (ha) = ƒ(population (# of individuals)).

If model results are statistically significant ($p \leq 0.05$) and unbiased (i.e. minimal trend in residuals), with an adjusted R-squared ≥ 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:

$$Pop_{i,t*} = Pop_{i,t2} + \frac{Pop_{i,t2} - Pop_{i,t1}}{t2 - t1} * (t^* - t_2) \quad (10)$$

Where:

$Pop_{i,t*}$	Projected population in census unit *i* in year *t**; # of individuals
$Pop_{i,t2}$	Population in census unit *i* at t_2 (most recent census date preceding project start date); # of individuals
$Pop_{i,t1}$	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:

$$Pop_{i,t*} = Pop_{i,t2} * \left(\frac{Pop_{i,t2}}{Pop_{i,t1}}\right)^{\left(\frac{t*-t2}{t2-t1}\right)} \quad (11)$$

Where:

$Pop_{i,t*}$	Projected population in census unit *i* in year *t**; # of individuals
$Pop_{i,t2}$	Population in census unit *i* at t_2 (most recent census date preceding project start date); # of individuals
$Pop_{i,t1}$	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:

$$A_{BSL,i,j,unplanned,t} = (Pop_{i,t} - Pop_{i,t-1}) * DP_j \quad (12)$$

Where:

$A_{BSL,i,j,unplanned,t}$	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^{-1}
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 $A_{BSL,i,unplanned,t}$ 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 $A_{BSL,i,unplanned,t}$ 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 $A_{BSL,i,unplanned,t}$ 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_j, 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)[19]. 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:

$$A_{BSL,RRD,unplanned,t} = \sum_{j}^{N} \sum_{i}^{M} A_{BSL,i,unplanned,j,t} \qquad (13)$$

Where:

$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in the reference region in year *t;* ha
$A_{BSL,i,unplanned,j,t}$	Projected area of unplanned baseline deforestation in census unit *i* member of *RRL* subset *j* in year *t;* ha
i	*1, 2, 3, …M* population census units
j	*1, 2, 3, …N* subsets of *RRL*
t	1, 2, 3, … *t* years elapsed since the projected start of the REDD project activity

PART 3. LOCATION AND QUANTIFICATION OF THREAT OF UNPLANNED DEFORESTATION

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

STEP 3.0 Determination of whether location analysis is required

STEP 3.1 Preparation of data sets for spatial analysis

STEP 3.2 Preparation of risk maps for deforestation

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

STEP 3.4 Mapping of the locations of future deforestation

STEP 3.0: Determination of whether location analysis is required

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

a. Mosaic Configuration

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[19] Note that in conformance with VCS AFOLU Guidance Section 4.4.8, where RRL subsets are justified on the basis of "…infrastructure (eg, roads) that does not yet exist", clear evidence shall 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.

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

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

b. Transition Configuration

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

c. Frontier Configuration

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

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

STEP 3.1: Preparation of data sets for spatial analysis

3.1.1 Requirements of spatial models

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

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

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

anthropogenic factors, and factors related to land tenure and management. Within these classes, the following factors shall be considered at a minimum:

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

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

STEP 3.2 Preparation of deforestation risk maps

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

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

STEP 3.3 Selection of the most accurate deforestation risk map

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

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

$$FOM = \frac{CORRECT}{CORRECT + Err_A + Err_B} \tag{15}$$

Where,

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

The minimum threshold for the best fit as measured by the Figure of Merit (FOM) 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.

- Select the stratum with the lowest carbon stock (see Step 3.2.1);

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

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

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

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

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

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

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

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 areas 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 first baseline period). The result is the *Map of Baseline Deforestation for Year 1* (or first baseline period, respectively).
- Repeat the above pixel selection procedure for each successive project year (or baseline period) to produce a *Map of Baseline Deforestation* for each future project year (or monitoring period). Do this at least for the upcoming 10-year baseline period and, optionally, for the entire project duration.
- Add all yearly (or periodical) baseline deforestation maps in one single map showing the expected *Baseline Deforestation for the Baseline Period* and, optionally, *Project Duration*.
- Prepare a table showing the number of hectares that will be deforested each year in the baseline case for the baseline period in the project area. In addition, prepare a Crediting Period Baseline Deforestation Map showing the hectares projected to be deforested in each year in the fixed (10 year) baseline period.

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

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

The methodology procedure is divided in the following five steps:

STEP 4.1 Stratification of the total area subject to deforestation

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

STEP 4.3 Estimation of the sum of baseline carbon stock changes

STEP 4.4 Estimation of the sum of baseline greenhouse gas emissions

STEP 4.5 Calculation of net CO_2 equivalent emissions

STEP 4.1: Stratification

Pre-deforestation strata (forest strata)

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

Post-deforestation strata (non-forest land uses)

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

STEP 4.2: Estimation of carbon 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 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.

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

4.2.2 Estimation of post-deforestation carbon stocks

Post-deforestation carbon stocks are assumed to be the long-term average stocks on the land following deforestation (time-weighted average of stocks in a given cyclical post-deforestation land-uses systems such as shifting agriculture with fallow). These stocks depend on the assumed land-uses after deforestation in each post-deforestation land-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. An historical mix of post-deforestation land-uses is assumed to be representative of future changes. The area-weighted average of the mature carbon stock for each land use is calculated from the historical land-use change matrix and is assumed to represent all post-deforestation carbon stocks in that land use during the project term. Note that in cyclical post-deforestation land-use systems the time-weighted average of stocks in a cycle shall be used. The historical reference period shall be used as the time-frame reference.

Post-deforestation carbon stocks of the selected land-use classes shall be obtained from local studies and, where examples of mature vegetation for a particular land-use do not exist in the reference area then data shall be obtained from credible and representative literature sources (e.g. IPCC GL 2006 or other credible literature sources). The local study areas shall include sites that represent the conditions and the land management practices identified as the most likely post-deforestation baseline conditions. Local data shall be based on a sampling scheme that produces conservative estimates of the carbon stocks[23]. 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.

$$\Delta C_{AB_{tree},i} = C_{AB_{tree_{bsl}},i} - C_{AB_{tree_{post}},i} \quad (16)$$

$$\Delta C_{AB_{non-tree},i} = C_{AB_{non-tree_{bsl}},i} - C_{AB_{non-tree_{post}},i} \quad (17)$$

$$\Delta C_{BB\_tree,i} = C_{BB_{tree_{bsl}},i} - C_{BB_{tree_{post}},i} \quad (18)$$

$$\Delta C_{BB_{non-tree},i} = C_{BB_{non-tree,bsl,i}} - C_{BB_{non-tree,post,i}} \quad (19)$$

$$\Delta C_{DW,i} = C_{DW,bsl,i} - C_{DW,post,i} \quad (20)$$

$$\Delta C_{LI,i} = C_{LI,bsl,i} - C_{LI,post,i} \quad (21)$$

23 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.

$$\Delta C_{SOC,i} = C_{SOC,bsl,i} - C_{SOC,PD-BSL,i} \quad (22)$$

Where:

$\Delta C_{AB\_tree,i}$	Baseline carbon stock change in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_tree,bsl,i}$	Forest carbon stock in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_tree,post,i}$	Post-deforestation carbon stock in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{BB\_tree,i}$	Baseline carbon stock change in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_tree,bsl,i}$	Forest carbon stock in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_tree,post,i}$	Post-deforestation carbon stock in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{AB\_non\text{-}tree,i}$	Baseline carbon stock change in aboveground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_non\text{-}tree,bsl,i}$	Forest carbon stock in aboveground non-tree vegetation in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_non\text{-}tree,post,i}$	Post-deforestation carbon stock in aboveground non-tree vegetation in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{BB\_non\text{-}tree,i}$	Baseline carbon stock change in belowground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_nontree,bsl,i}$	Forest carbon stock in belowground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_nontree,post,i}$	Post-deforestation carbon stock in belowground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{DW,i}$	Baseline carbon stock change in dead wood in stratum *i*; t CO_2-e ha^{-1}
$C_{DW,bsl,,i}$	Forest carbon stock in dead wood in stratum *i*; t CO_2-e ha^{-1}
$C_{DW,post,,i}$	Post-deforestation carbon stock in dead wood in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{LI,i}$	Baseline carbon stock change in litter in stratum *i*; t CO_2-e ha^{-1}
$C_{LI,bsl,i}$	Forest carbon stock in litter in stratum *i*; t CO_2-e ha^{-1}
$C_{LI,post,i}$	Post-deforestation carbon stock in litter in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{SOC,i}$	Baseline carbon stock change in soil organic carbon in stratum *i*; t CO_2-e ha^{-1}
$C_{SOC,bsl,,i}$	Forest carbon stock in soil organic carbon in stratum *i*; t CO_2-e ha^{-1}
$C_{SOC,PD\text{-}BSLi}$	Post-deforestation carbon stock in soil organic carbon in stratum *i*; t CO_2-e ha^{-1}
i	1, 2, 3, … *M strata*

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 (CP-W) shall be included. For calculation of carbon stock sequestered in wood products, see 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

$$\Delta C_{TOT} = \sum_{t=1}^{t} \sum_{i=1}^{M} \Delta C_{BSL,i,t} \quad (23)$$

$$\Delta C_{BSL,i,t} = A_{unplanned,i,t} * (\Delta C_{AB_{tree},i} + \Delta C_{AB_{non-tree},i} + \Delta C_{LI,i})$$
$$+ (\sum_{t-10}^{t} A_{unplanned,i,t}) * (\Delta C_{BB_{tree},i} + \Delta C_{BB_{non-tree},i} + \Delta C_{DW,i}) * \left(\frac{1}{10}\right)$$
$$+ (\sum_{t-20}^{t} A_{unplanned,i,t}) * \left(C_{WP100,i} + \Delta C_{SOC,i}\right) * \left(\frac{1}{20}\right) \quad (24)$$

Where:

ΔC_{TOT}	Sum of the baseline carbon stock change in all pools up to time *t**; t CO_2-e (calculated separately for the project area [PA] and the leakage belt [LB]
$\Delta C_{BSL,i,t}$	Sum of the baseline carbon stock change in all pools in stratum *i* at time *t,* t CO_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_2-e ha^{-1}
$\Delta C_{AB\_tree,i}$	Baseline carbon stock change in aboveground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{BB\_tree,i}$	Baseline carbon stock change in belowground tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{AB\_non-tree,i}$	Baseline carbon stock change in aboveground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{BB\_non-tree,i}$	Baseline carbon stock change in belowground non-tree biomass in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{DW,i}$	Baseline carbon stock change in dead wood in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{LI,i}$	Baseline carbon stock change in litter in stratum *i*; t CO_2-e ha^{-1}
$\Delta C_{SOC,i}$	Baseline carbon stock change in soil organic carbon in stratum *i*; t CO_2-e ha^{-1}
i	1, 2, 3, … *M* strata
t	1, 2, 3, … *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:

$$GHG_{BSL,E} = \sum_{t=1}^{t^*} \sum_{i=1}^{M} \left(E_{FC,i,t} + E_{BiomassBurn,i,t} + N_2O_{direct-N,i,t} \right) \quad (25)$$

Where:

$GHG_{BSL,E}$	Greenhouse gas emissions as a result of deforestation activities within the project boundary in the baseline; t CO_2-e

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

For detailed information regarding the calculation of $E_{FC,i,t}$, $E_{BiomassBurn,i,t}$ and $N_2O_{direct\text{-}N,i,t}$ see E-FFC, E-BB and E-NA.

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

$$\Delta C_{BSL,unplanned} = \Delta C_{BSL,PA,unplanned} + GHG_{BSL,E} \quad (26)$$

$$\Delta C_{BSL,PA,unplanned} = \Delta C_{TOT,PA} \quad (27)$$

$$\Delta C_{BSL,LK,unplanned} = \Delta C_{TOT,LB} \quad (28)$$

Where:

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

6 PARAMETERS

Data / parameter:	$Pop_{i,t}$
Data unit:	Number of individuals per population census unit *i* in year *t*
Used in equations:	10,11,12
Description:	Periodic population census data
Source of data:	Official sources or through independent representative surveys

Measurement procedures (if any):	
Monitoring frequency:	Must be updated every 10 years
QA/QC procedures:	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[24]
Any comment:	

Data / parameter:	DP_j
Data unit:	ha * # of individuals^{-1}
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

[24] Available at http://unstats.un.org/unsd/demographic/sources/census/docs/P&R_%20Rev2.pdf

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:	
Any comment:	

Data / parameter:	$P_{2,i}$
Data unit:	# of individuals
Used in equations:	9
Description:	number of new children born to household *i* since immigrating and 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:	
Any comment:	

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

Data / parameter:	Risk Maps
Data unit:	

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

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

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

Data / parameter:	*Correct*
Data unit:	ha
Used in equations:	15

Description:	Area correct due to observed change predicted as change
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	Err_A
Data unit:	ha
Used in equations:	15
Description:	Area of error due to observed change predicted as persistence
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	Err_B
Data unit:	ha
Used in equations:	15
Description:	Area of error due to observed persistence predicted as change
Source of data:	Spatial model of deforestation location
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

Data / parameter:	*FOM*
Data unit:	
Used in equations:	
Description:	Figure of Merit
Source of data:	Calculated using equation 10.
Measurement procedures (if any):	

Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
QA/QC procedures:	
Any comment:	

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

Data / parameter:	LSC_{RRL}
Data unit:	Ha
Used in equations:	14
Description:	The area of *RRL* suitable for conversion from forest to an alternate land use
Source of data:	
Measurement procedures (if any):	Calculated from the result of analysis of forest areas in the reference region for projection of location of deforestation with regard to constraints to deforestation (including elevation, climate, protected status etc). Uses parameter $A_{RRL,forest,t}$ derived from M-MON
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	*PA*
Data unit:	Ha

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

Data / parameter:	P_{LK}
Data unit:	Dimensionless
Used in equations:	6
Description:	Ratio of the area of the leakage belt to the total area of *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	$P_{LSC,RRL}$
Data unit:	Dimensionless
Used in equations:	14
Description:	Ratio of the parameter LSC_{RRL} to the area of the *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited)

	Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

Data / parameter:	P_{PA}
Data unit:	dimensionless
Used in equations:	5
Description:	Ratio of the Project Area to the total area of *RRD*
Source of data:	
Measurement procedures (if any):	Calculated from the result of remotely sensed data analysis
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Monitored at least once every 10 years (when the baseline is revisited) Shall be estimated at time zero, this estimate shall be used for *ex-ante* purposes

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

Data / parameter:	*RRD*
Data unit:	Ha
Used in equations:	
Description:	Geographic boundaries of the reference area for projection of rate of deforestation
Source of data:	GPS coordinates and/or remote sensing data
Measurement	

procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	

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

Data / parameter:	T_{hrp}
Data unit:	Yr
Used in equations:	3
Description:	Duration of the historical reference period in years
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	Must be updated each time the baseline is revisited (at least every 10 years)
Quality Assurance / Quality Control	
Any comment:	Must be between 10 and 15 years

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

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

Data / parameter:	$C_{AB\_tree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in aboveground biomass in trees in stratum *i*
Module parameter originates in:	CP-AB
Any comment:	

Data / parameter:	$C_{BB\_tree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in belowground biomass in trees in stratum *i*
Module parameter originates in:	CP-AB
Any comment:	

Data / parameter:	$C_{AB\_nontree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in aboveground non-tree vegetation in stratum *i*
Module parameter originates in:	CP-AB
Any comment:	Herbaceous vegetation considered *de minimis* in all instances

Data / parameter:	$C_{BB\_nontree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in belowground non-tree vegetation in stratum *i*

Module parameter originates in:	CP-AB
Any comment:	Herbaceous vegetation considered *de minimis* in all instances

Data / parameter:	$C_{DW,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in dead wood in stratum *i*
Module parameter originates in:	CP-W
Any comment:	

Data / parameter:	$C_{LI,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12,13
Description:	Carbon stock in litter in stratum *i*
Module parameter originates in:	CP-L
Any comment:	

Data / parameter:	$C_{SOC,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	12
Description:	Carbon stock in soil organic carbon in the baseline in stratum *i*
Module parameter originates in:	CP-S
Any comment:	

Data / parameter:	$C_{SOC,PD-BSL,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	13
Description:	Mean post-deforestation stock in soil organic carbon in the post deforestation stratum *i*
Module parameter originates in:	CP-S
Any comment:	

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

Data unit:	t CO_2-e ha^{-1}
Used in equations:	17
Description:	Mean carbon stock in wood products pool (stock remaining in wood products after 100 years) from stratum *i*
Module parameter originates in:	CP-W
Any comment:	

Data / parameter:	$E_{BiomassBurn,i,t}$
Data unit:	t CO_2-e
Used in equations:	18
Description:	Non-CO_2 emissions due to biomass burning as part of degradation activities in stratum *i* in year *t*
Module parameter originates in:	E-BB
Any comment:	

Data / parameter:	$E_{FC,i,t}$
Data unit:	t CO_2-e
Used in equations:	18
Description:	CO_2 emission from fossil fuel combustion in stratum *i* in year *t*
Module parameter originates in:	E-FFC
Any comment:	

Data / parameter:	$N_2O_{direct\text{-}N,i,t}$
Data unit:	t CO_2-e
Used in equations:	18
Description:	Direct N_2O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum *i* in year *t*
Module parameter originates in:	E-NA
Any comment:	

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

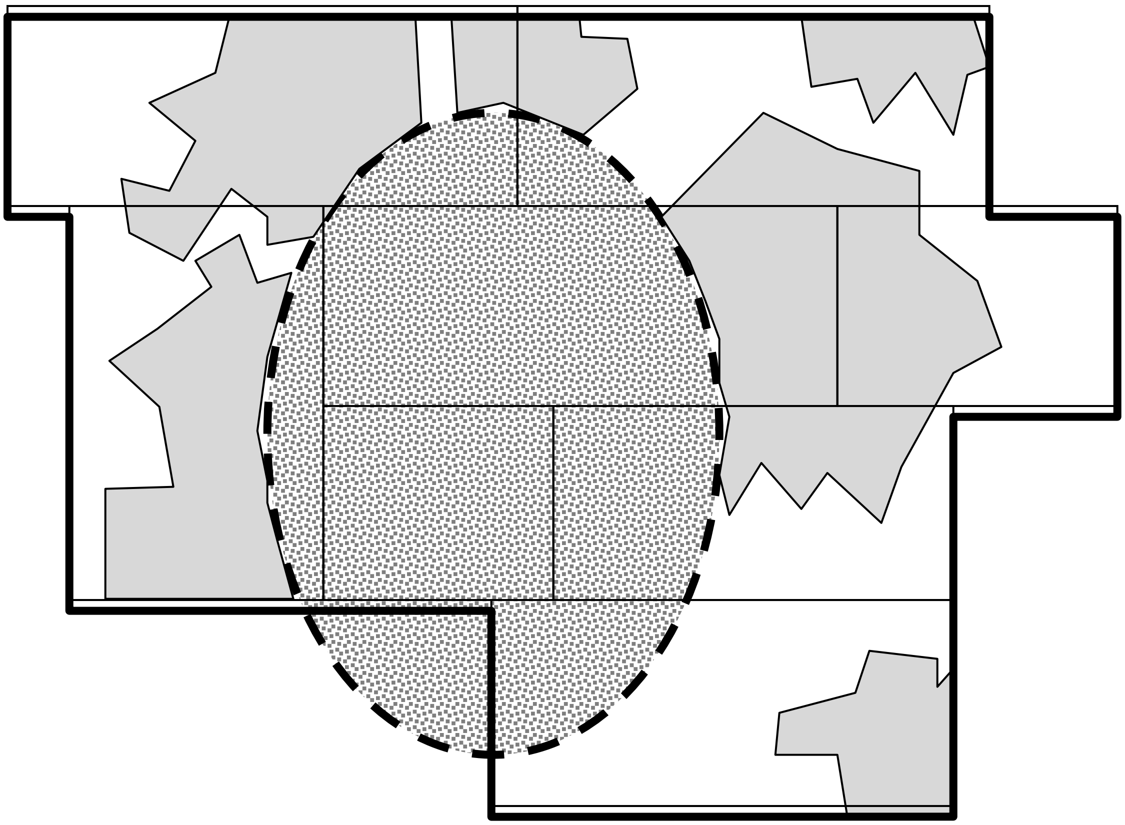
	beginning of the crediting period
Module parameter originates in:	M-MON
Any comment:	

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

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

7 REFERENCES AND OTHER INFORMATION

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

Version	Date	Comment
v1.0	3 Dec 2010	Initial version released
v2.0	7 Sept 2011	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.
v3.0	19 July 2012	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.
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.