VCS | VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

Approved VCS Methodology
VM0015

Version 1.0
Sectoral Scope 14

Methodology for
Avoided Unplanned Deforestation

Acknowledgements

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Source

This methodology is based on the draft REDD-PD for the "Reserva do Juma Conservation Project" in Amazonas (Brazil), whose *baseline* study, monitoring and project design documents were prepared by IDESAM, the Amazonas Sustainable Foundation (FAS) and the Government of Amazonas (SDS/SEPLAN-AM), with inputs and review from a selected group of experts and scientists in Brazil. The methodology is an adaptation to all kinds of "*Unplanned Deforestation*" of the draft methodology for "*Mosaic Deforestation*" developed by the BioCarbon Fund for the REDD project activity "Ankeniheny - Zahamena Biological Corridor" in Madagascar, whose baseline study, monitoring and project design documents are being prepared by the Ministry of the Environment, Water, Forests and Tourism of Madagascar with assistance of Conservation International and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund.

Scope

The methodology is for estimating and monitoring greenhouse gas (GHG) emissions of project activities that avoid unplanned deforestation (AUD) and enhance carbon stocks of forests that would be deforested in the baseline case. The forest landscape configuration can be either mosaic or frontier[1]. Credits for reducing GHG emissions from avoided degradation are excluded in this methodology.

The methodology has no geographic restrictions and is applicable globally.

The project area in the baseline case may include any types of forest, such as, but not limited to, old growth-forests, degraded (and perhaps still degrading) forests, and secondary forests with more than 10 years of age at the project start date. Forests in the baseline case may be subject to planned or unplanned logging for timber, fuel wood collection or charcoal production, but not to planned deforestation.

The project activity may involve logging for timber, fuel wood collection or charcoal production and even some level of controlled deforestation when this is unavoidable to implement the AUD project. Project proponents are not seeking credits for avoided degradation[2], and therefore during the project lifetime:

(i) GHG emission reductions in areas that would be degraded (but not deforested) in the baseline case within the project area are not claimed; and

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[1] The most recent VCS definitions of "mosaic deforestation" and "frontier configuration" shall be used in applying this methodology. According to the VCS Program Update of May 24th, 2010 "Mosaic configurations are defined as any landscape in which no patch of forest in the project area exceeds 1000 ha and forest patches are surrounded by anthropogenically cleared land. "Frontier configurations are defined as any landscape in which all forest areas in the project area have no current direct physical connection with areas anthropogenically deforested".

[2] If project proponents want to claim credits for reducing GHG emissions from avoided degradation, an approved VCS methodology for Improved Forestry Management (IFM) shall be applied in the strata where degradation is reduced. Such strata shall be removed from the areas of the AUD project activity. Areas of the IFM and AUD project activities shall not overlap.

(ii) Leakage from avoided degradation in areas that would be degraded (but not deforested) in the baseline case, which may occur as a consequence of the AUD project activity, is assumed to be similar to the avoided degradation and must not be quantified.

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SUMMARY

This methodology is for estimating and monitoring greenhouse gas (GHG) emissions of project activities that avoid unplanned deforestation (AUD). It also gives the option to account for carbon stock enhancements in forests that would be deforested in the baseline case, when these are measurable and significant. Credits for reducing GHG emissions from avoided degradation are excluded in this methodology.

The methodology has no geographic restrictions and is applicable globally under the following conditions:

a) Baseline activities may include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities as long as the category is unplanned deforestation according to the most recent VCS AFOLU guidelines.

b) Project activities may include one or a combination of the eligible categories defined in the description of the scope of the methodology (see table 1 and figure 2).

c) The project area can include different types of forest, such as, but not limited to, old-growth forest, degraded forest, secondary forests, planted forests and agro-forestry systems meeting the definition of "forest".

d) At project commencement, the project area shall include only land qualifying as "forest" for a minimum of 10 years prior to the project start date.

e) The project area can include forested wetlands (such as bottomland forests, floodplain forests, mangrove forests) as long as they do not grow on peat. Peat shall be defined as organic soils with at least 65% organic matter and a minimum thickness of 50 cm. If the project area includes a forested wetlands growing on peat (e.g. peat swamp forests), this methodology is not applicable.

The methodology requires the use of existing deforestation baselines if these meet the applicability criteria of the methodology.

Leakage in this methodology is subject to monitoring, reporting, verification and accounting (MRV-A). However, if the project area is located within a broader sub-national or national region that is subject to MRV-A of GHG emissions from deforestation under a VCS or UNFCCC registered (and VCS endorsed) program (= "jurisdictional program"), leakage may be subject to special provisions because any change in carbon stocks or increase in GHG emissions outside the project area would be subject to MRV-A under the broader jurisdictional program. In such cases, the most recent VCS guidelines on this subject matter shall be applied[3].

The methodology defines four spatial domains: a broad "reference region", the "project area", a "leakage belt", and a "leakage management area". The project area, leakage belt and leakage management areas are subsets of the reference region and are always spatially distinct (not overlapping) areas (see figure 1).

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[3] At the sixteenth Conference of the Parties to the UNFCCC in Cancun (Mexico), the VCS Association announced its intention to develop new standards for regional baselines and jurisdictional programs. This is anticipated in this methodology.

Figure 1. Spatial domains considered in this methodology

a) Frontier configuration

Legend:

- Reference Region
- Project Area
- Leakage Management Areas
- Leakage Belt
- Forest
- No-Forest
- Deforestation occurred during the historical reference period
- Projected deforestation on currently forested land.
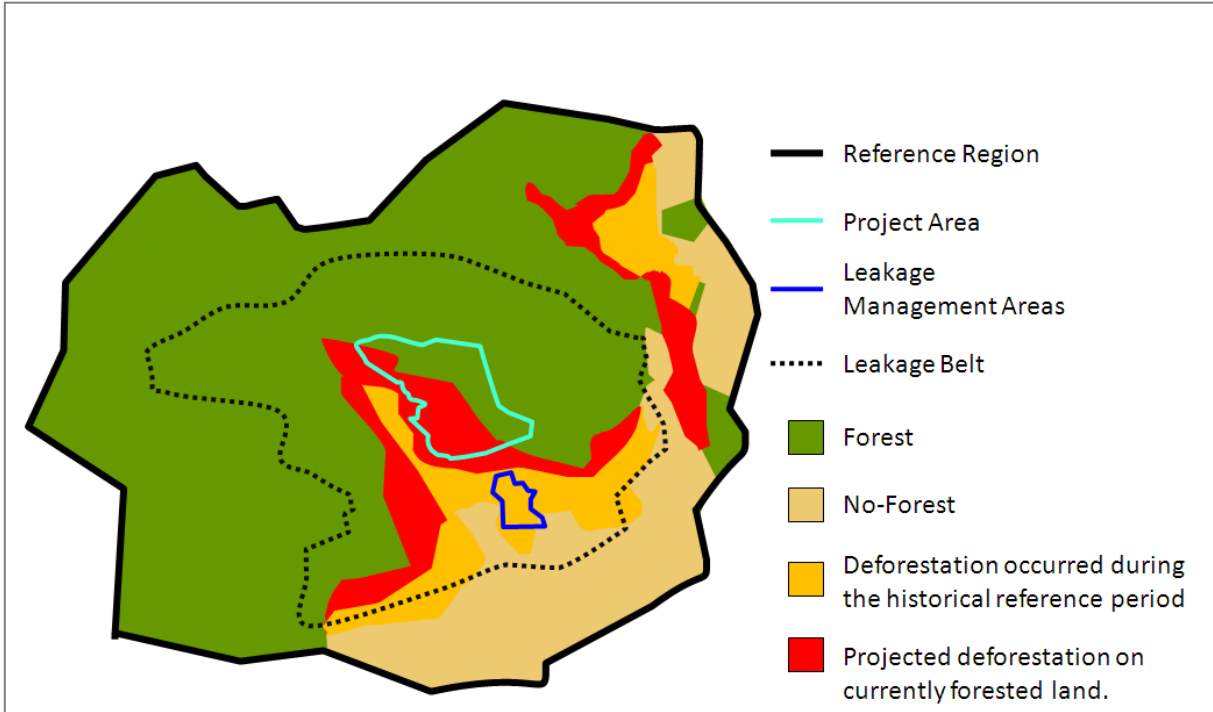
b) Mosaic configuration
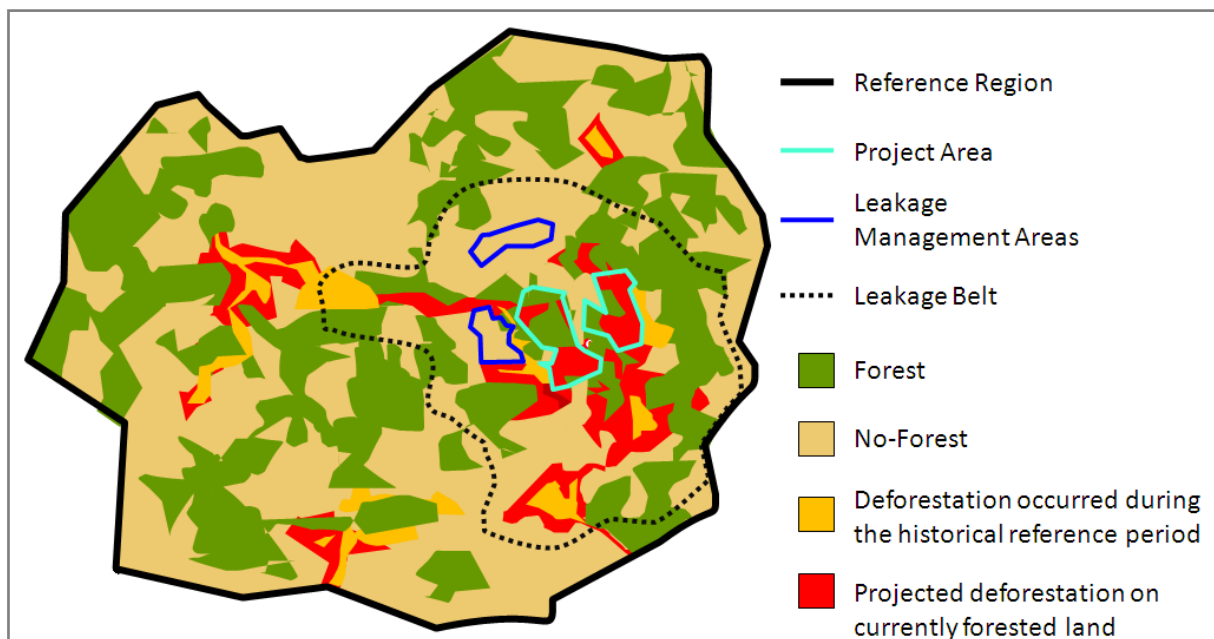
- The "reference region" is the analytical domain from which information on historical deforestation is extracted and projected into the future to spatially locate the area that will be deforested in the baseline case.

- The "project area" is the area (or areas) under the control of the project participants in which the AUD project activity will be implemented and GHG emission reductions accounted.

- The "leakage belt" is the area where any deforestation above the baseline projection will be considered leakage. It must be defined only if MRV-A for leakage is required.

- The "leakage management area" is the area (or areas) specifically designed to implement activities that reduce the risk of activity displacement leakage. These are areas dedicated to enhanced crop-land and grazing land management, agro-forestry, silvo-pastoral activities and reforestation activities. At the project start date, leakage management areas shall be non-forest land.

The baseline projections must be revisited every 10 years and adjusted, as necessary, based on land-use and land-cover changes observed during the past period and changes at the level of agents, driver and underlying causes of deforestation, which are subject to monitoring. The period of time during which a validated baseline must not be reassessed is called "fixed baseline period" in this methodology. The baseline may be reassessed before the fixed 10 year baseline expires only if an applicable jurisdictional baseline becomes available.

The boundary of the leakage belt must be revisited at the end of each fixed baseline period and any time when an AFOLU project located in the project´s leakage belt area is registered under

the VCS. In such case, the project area of the new AFOLU project must be excluded from the leakage belt area from the date of its registration[4]. Changes in the leakage belt boundary shall be monitored and are subject to VCS verification.

Emissions of non-CO_2 gases in the baseline are conservatively omitted, except CH_4 emissions from biomass burning, which can be counted when fire is the main technology used to deforest and when the project proponent considers that ignoring this source of emissions would substantially underestimate the baseline emissions. However, CH_4 emissions from forest fires in the project case must be accounted when they are significant.

If leakage must be estimated and accounted, then the methodology considers two potential sources of leakage:

(i)   If more deforestation in the leakage belt area is observed during project implementation, this will be considered as activity displacement leakage, and the decrease in carbon stocks and increase of GHG emissions (if emissions from forest burning are included in the baseline) must be subtracted in the calculation of the project's net anthropogenic GHG emissions reductions.

(ii)   If leakage prevention measures include tree planting, agricultural intensification, fertilization, fodder production and/or other measures to enhance cropland and grazing land areas in leakage management areas, then any decrease in carbon stocks and increase in GHG emissions associated with these activities is estimated and subtracted in the calculation of the project's net anthropogenic emissions reductions.

Any decrease in carbon stock or increase in GHG emissions attributed to the project activity must be accounted when it is significant, otherwise it can be neglected. Significance in this methodology is assessed using the most recent CDM-approved and VCS-endorsed version of the "Tool for testing significance of GHG emissions in A/R CDM project activities"[5].

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[4]   This is to avoid double counting of emissions when a new VCS AFOLU registered project and/or its leakage belt are located (partially or totally) in the leakage belt of the proposed AUD project.

[5]   Available at: http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

METHODOLOGY DESCRIPTION

PART 1 – SCOPE, APPLICABILITY CONDITIONS AND ADDITIONALITY

1   Scope of the methodology

This methodology is for estimating and monitoring GHG emissions of project activities that avoid unplanned deforestation (AUD). The forest landscape configuration can be mosaic, frontier or a transition between the two. Carbon stock enhancements in forests that would be deforested in the baseline case can also be accounted under this methodology. However, credits for reducing GHG emissions from avoided degradation are excluded.

Baseline activities and project activities may include harvesting of timber, fuel-wood collection and charcoal production[6]. Project activities may include some level of planned deforestation, but planned deforestation is excluded from the baseline.

The eligible categories of project activity covered by this methodology are represented with the letters **A** to **H** in table 1 and figure 2.

Table 1. Scope of the methodology
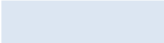
<table>
<tr><td colspan="3"></td><td colspan="2">PROJECT ACTIVITY</td></tr>
<tr><td colspan="3"></td><td>Protection without logging, fuel wood collection or charcoal production</td><td>Protection with controlled logging, fuel wood collection or charcoal production</td></tr>
<tr><td rowspan="8">BASELINE</td><td rowspan="4">Deforestation</td><td>Old-growth without logging</td><td>A</td><td>B</td></tr>
<tr><td>Old-growth with logging</td><td>C[1]</td><td>D[1]</td></tr>
<tr><td>Degraded and still degrading</td><td>E[1]</td><td>F[1]</td></tr>
<tr><td>Secondary growing</td><td>G[1]</td><td>H[1]</td></tr>
<tr><td rowspan="4">No-deforestation[2]</td><td>Old-growth without logging</td><td>No change</td><td>Degradation</td></tr>
<tr><td>Old-growth with logging</td><td>IFM</td><td>IFM-RIL</td></tr>
<tr><td>Degraded and still degrading</td><td>IFM</td><td>IFM</td></tr>
<tr><td>Secondary growing</td><td>No change</td><td>Degradation</td></tr>
</table>

1. Accounting for carbon stock increase in the project scenario is optional and can conservatively be omitted.

2. If the baseline is not deforestation, the change in carbon stocks is not covered in this methodology.

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[6]   Accounting for carbon stock decrease due to timber harvesting, fuel-wood collection and charcoal production is mandatory in both the baseline and project scenarios if the decrease is significant. The increase of carbon stocks in forests that would be deforested in absence of the project activity is optional in this methodology and can conservatively be omitted.

Figure 2. Categories included in the scope of this methodology

Notations

——— (red)	Historical carbon stocks
- - - - (red dashed)	Projected carbon stocks (Baseline)
——— (green)	Project scenario carbon stocks
▮ (dark blue)	Emission reductions always claimed
▯ (light blue)	Emission reductions optionally claimed
○ (yellow)	Mandatory *ex ante* measurements
○ (orange)	Optional *ex post* measurements (for optional emission reduction credits)
● (red)	Mandatory *ex post* measurements

A - Avoided Deforestation without Logging
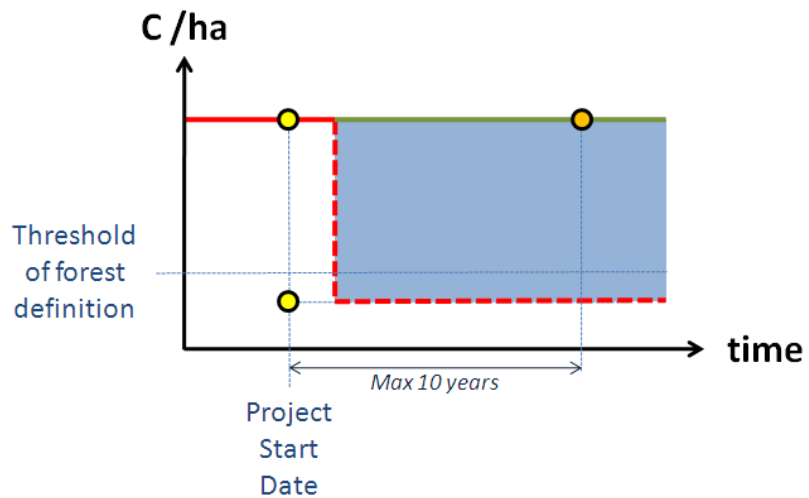
B – Avoided Deforestation with Logging in the Project Case
+ Carbon Stock Increase (optional)
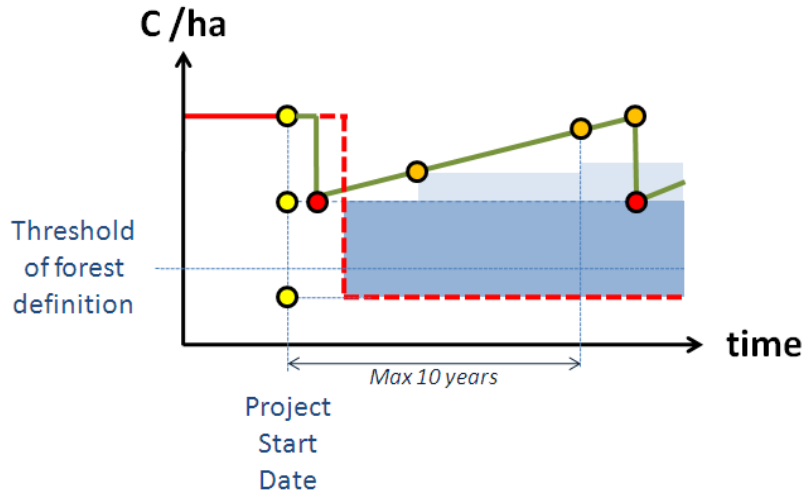
C – Avoided Deforestation with Logging Suppression
+ Carbon Stock Increase (optional)
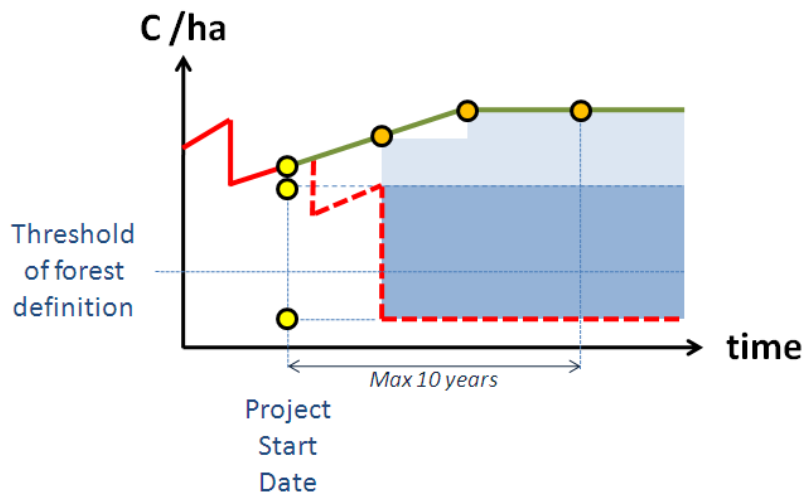
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

D – Avoided Deforestation with Logging in the Baseline and Project Cases
+ Carbon Stock Increase (optional)
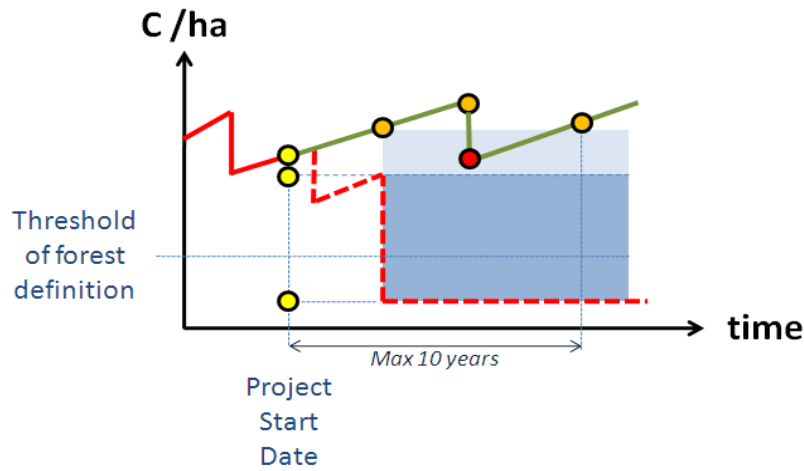
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

E - Avoided Deforestation of Degrading Forest
+ Carbon Stock Increase (optional)
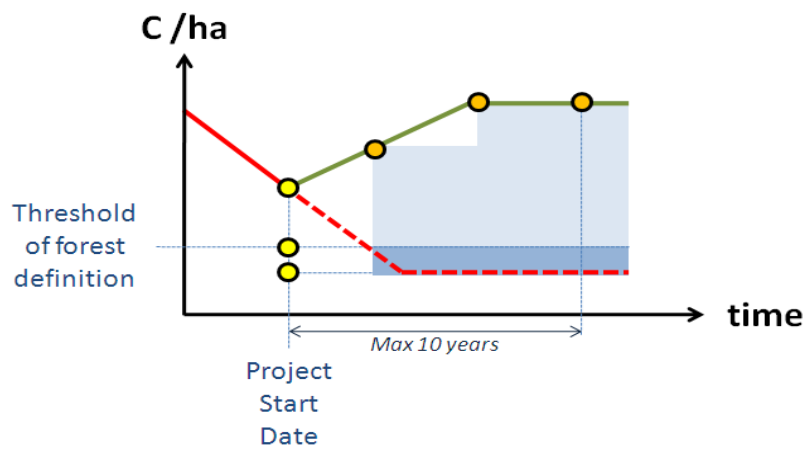
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

F - Avoided Deforestation of Degrading Forest with Logging in the Project Case
+ Carbon Stock Increase (optional)
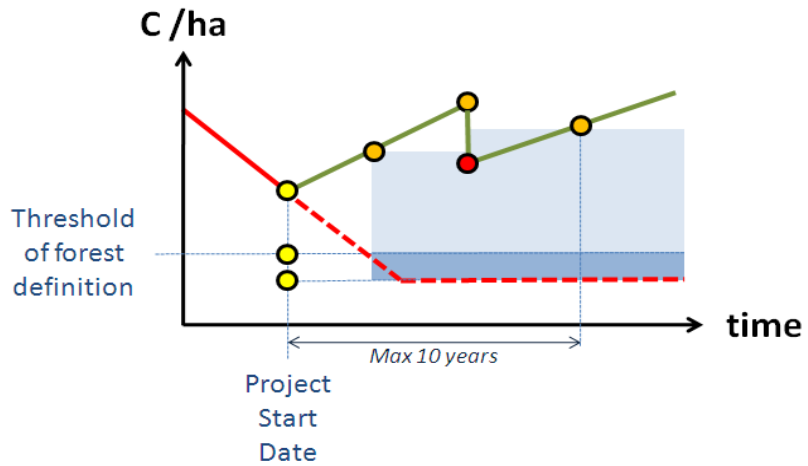
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

G – Avoided Deforestation of Secondary Forest
+ Carbon Stock Increase (optional)
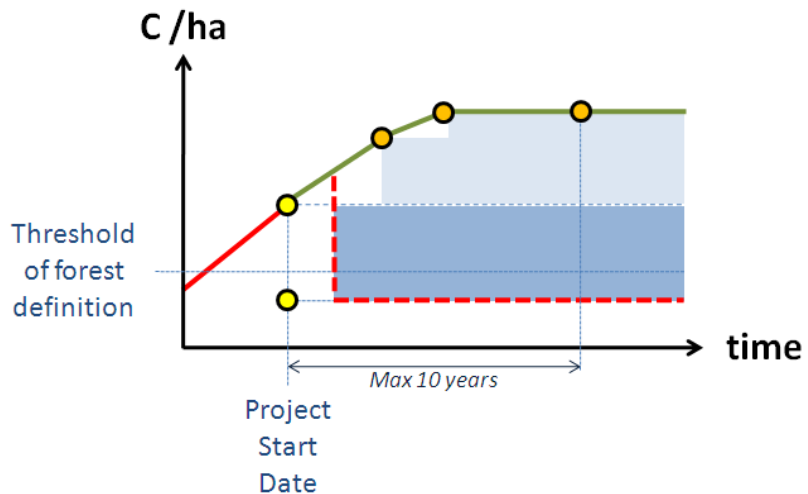
**H – Avoided Deforestation of Secondary Forest
with Logging in the Project Case
+ Carbon Stock Increase (optional)**
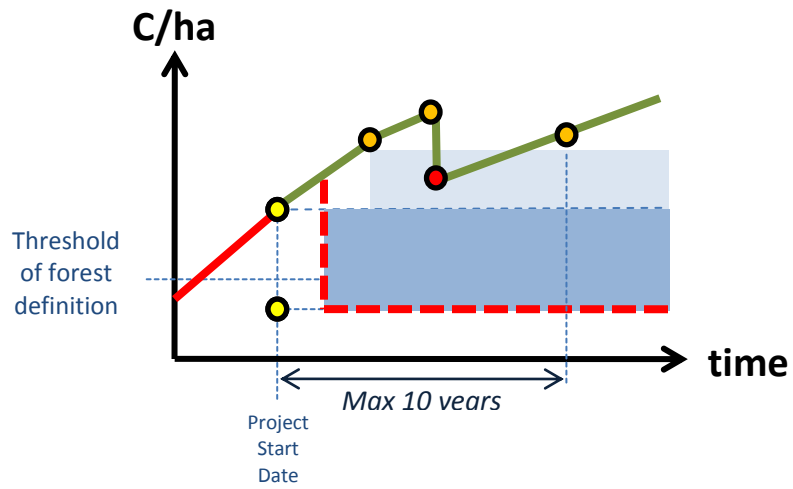
2   Applicability conditions

The methodology has no geographic restrictions and is applicable globally under the following conditions:

a) Baseline activities may include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities as long as the category is unplanned deforestation according to the most recent VCS AFOLU requirements.

b) Project activities may include one or a combination of the eligible categories defined in the description of the scope of the methodology (table 1 and figure 2).

c) The project area can include different types of forest, such as, but not limited to, old-growth forest, degraded forest, secondary forests, planted forests and agro-forestry systems meeting the definition of "forest".

d) At project commencement, the project area shall include only land qualifying as "forest" for a minimum of 10 years prior to the project start date.

e) The project area can include forested wetlands (such as bottomland forests, floodplain forests, mangrove forests) as long as they do not grow on peat. Peat shall be defined as organic soils with at least 65% organic matter and a minimum thickness of 50 cm. If the project area includes a forested wetlands growing on peat (e.g. peat swamp forests), this methodology is not applicable.

Demonstrate that the methodology is applicable to the proposed AUD project activity.

3   Additionality

Additionality of the proposed AUD project activity must be demonstrated using either the most recent VCS-approved "Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities"[7] noting the following:

The earliest start date of the proposed AUD project activity is January 1st, 2002. However, the start date can be earlier than January 1st, 2002, provided the requirements for projects with a start date prior to 2002, as set out in the most recent version of the VCS Standard, are met.

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[7]   Available at www.v-c-s.org

PART 2 - METHODOLOGY STEPS FOR EX-ANTE ESTIMATION OF GHG EMISSION REDUCTIONS

The nine methodology steps that will lead to the calculation of *ex ante* net anthropogenic GHG emission reductions are summarized in Figure 3. In the PD refer to each of these steps and sub-steps using the same titles and numbers so that the application of the methodology can transparently be validated.

Figure 3. *Ex ante* methodology steps

Step 1. Definition of the boundaries of the proposed AUD project activity: spatial boundaries, temporal boundaries, carbon pools and sources of greenhouse gas emissions.

Step 2. Analysis of historical land-use and land-cover change in the reference region going back about 10-15 years from present.

Step 3. Analysis of agents, drivers and underlying causes of deforestation, and sequencing of the typical chain of events leading to land-use and land-cover change.

Step 4. Projection of the annual areas and location of deforestation in the reference region in the without project case.

Step 5. Identification of forest classes in the areas that will be deforested under the baseline scenario and of post-deforestation land-use classes in the project area.

Step 6. Estimation of baseline carbon stock changes and, where forest fires are included in the baseline assessment, of non-CO_2 emissions from biomass burning.

Step 7. *Ex ante* estimation of actual carbon stock changes and non-CO_2 emissions under the project scenario.

Step 8. *Ex ante* estimation of leakage associated to leakage prevention measures and activity displacement.

Step 9. *Ex ante* calculation of net anthropogenic GHG emission reductions.

Step 1: Definition of boundaries

The purpose of this step is to define the following categories of project boundaries:

    1.1   Spatial boundaries;

    1.2   Temporal boundaries;

    1.3   Carbon pools; and

    1.4   Sources of emissions of greenhouse gases (other than carbon stock changes).

1.1 Spatial boundaries

Define the boundaries of the following spatial features:

    1.1.1   Reference region;

    1.1.2   Project area;

    1.1.3   Leakage belt;

    1.1.4   Leakage management areas; and

    1.1.5   Forest.

The reference region is the largest unit of land and the project area, leakage belt and leakage management areas are subsets of the reference region. For each spatial feature, the criteria used to define their boundaries must be described and justified in the PD. Vector or raster files in a common projection and GIS software formats shall be provided in order to allow the identification of the boundaries unambiguously.

1.1.1 Reference region

The boundary of the reference region is the spatial delimitation of the analytic domain from which information about rates, agents, drivers, and patterns of land-use and land-cover change (LU/LC-change) will be obtained, projected into the future and monitored.

The reference region must contain strata with agents, drivers and patterns of deforestation that in the 10-15 year period prior to the start date of the proposed AUD project activity are similar to those expected to exist within the project area.

The boundary of the reference region shall be defined as follows:

1. If sub-national or national baselines exist, that meet VCS specific guidance on applicability of existing baselines, such baselines must be used. Any pre-existing baseline should be analyzed and if it meets the criteria listed in table 2, it should be used. In both cases, the existing baseline will determine the boundary of the reference region.

2. If no such applicable sub-national or national baseline is available, the national and, where applicable, sub-national government shall be consulted to determine whether the country or sub-national region has been divided in spatial units for which deforestation

baselines will be developed. If such divisions exist and are endorsed by the national or sub-national government, they must be used to determine the boundary of the reference region.

3. If such divisions do not exist, a baseline must be developed for a reference region encompassing the project area, the leakage belt and any other geographic area (stratum *i*) that is relevant to determine the baseline of the project area.

4. A geographic area is relevant for determining the baseline of the project area when agents, drivers and overall deforestation patterns observed in it during the 10-15 year period preceding the start date of the proposed AUD project activity represent a credible proxy for possible future deforestation patterns in the project area.

Table 2. Criteria determining the applicability of existing baselines

	Applicability criteria
1	The existing baseline must cover a broader geographical region than the project area. If a leakage belt must be defined[1], the broader region must include the leakage belt.
2	The existing baseline must cover at least the duration of the first fixed baseline period and is not outdated[2].
3	The existing baseline must depict the location of future deforestation on a yearly base.
4	The spatial resolution of the existing baseline must be equal or finer than the minimum mapping unit of "forest land" that will be used for monitoring deforestation during the fixed baseline period.
5	Methods used to develop the existing baseline must be transparently documented and be consistent with a VCS approved and applicable baseline methodology.

1. If the project area is located within a jurisdictional program the most recent VCS guidance on jurisdictional programs[8] must be applied to determine whether a leakage belt is required. In all other cases, a leakage belt is required.

2. A baseline is considered outdated 10 years after its establishment.

The reference region may include one or several discrete areas. It must be larger[9] than the project area and include the project area.

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8   At the sixteenth Conference of the Parties to the UNFCCC in Cancun (Mexico), the VCS Association announced its intention to develop new standards for regional baselines and jurisdictional programs. This is anticipated in this methodology.

9   Brown *et al*. (2007) suggest the following rule of thumb:
   - For projects above 100,000 ha, the reference region should be about 5-7 times larger than the project area.
   - For projects below 100,000 ha, the reference region should be 20-40 times the size of the project area.

   These figures are indicatives; the exact ratio between the two areas depends on the particular regional and project circumstances. Where a project activity deals with an entire island, the reference region must include other islands or forested landscapes with similar conditions.

Where the current situation within the project area is expected to change (e.g. because of population growth, infrastructure development or any other plausible reason), the reference region should be divided in *i* strata, each representing proxies for the chrono-sequence of current and future conditions within the project area. The boundary of such strata may be static (fixed during a fixed baseline period) or dynamic[10] (changing every year), depending on the modeling approaches used.

Three main criteria are relevant to demonstrate that the conditions determining the likelihood of deforestation within the project area are similar or expected to become similar to those found within the reference region

- **Agents and drivers of deforestation** expected to cause deforestation within the project area in absence of the proposed AUD project activity must exist or have existed elsewhere in the reference region. The following requirements are to be met:

  - **Agent groups**: Deforestation agent´s groups (as identified in step 3) expected to encroach into the project area must exist or have existed and caused deforestation elsewhere in the reference region during the historical reference period.

  - **Infrastructure drivers.** If new or improved infrastructure (such as roads, railroads, bridges, hydroelectric reservoirs, etc.) is expected to develop near or inside the project area[11], the reference region must include a stratum where such infrastructure was built in the past and where the impact on forest cover was similar to the one expected from the new or improved infrastructure in the project area.

  - **Other spatial drivers expected to influence the project area**. Any spatial deforestation driver considered relevant according to the analysis of step 3 (e.g. resettlement programs, mining and oil concessions, etc.) must exist or have existed elsewhere in the reference region. The historical impact of such drivers must have been similar to the one expected in the project area.

- **Landscape configuration and ecological conditions:** At least three of the following four conditions must be satisfied:

  - **Forest/vegetation classes:** At least 90% of the project area must have forest classes or vegetation types that exist in at least 90% of the rest of the reference region.

  - **Elevation:** At least 90% of the project area must be within the elevation range of at least 90% of the rest of the reference region.

  - **Slope:** The average slope of at least 90% of the project area shall be within ± 10% of the average slope of at least 90% of the rest of the reference region.

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[10] Dynamic = with shifting boundaries, according to modeled changes at the level of driver variables such as population, infrastructure and other to be determined by the project proponent.

[11] Areas of planned deforestation in the baseline case must be excluded from the project area.

- **Rainfall:** The average annual rainfall in at least 90% of the project area shall be within ± 10% of the average annual rainfall of at least 90% of the rest of the reference region.

- **Socio-economic and cultural conditions:** The following conditions must be met:

  - **Legal status of the land**: The legal status of the land (private, forest concession, conservation concession, etc.) in the baseline case within the project area must exist elsewhere in the reference region. If the legal status of the project area is a unique case, demonstrate that legal status is not biasing the baseline of the project area (e.g. by demonstrating that access to the land by deforestation agents is similar to other areas with a different legal status).

  - **Land tenure**: The land-tenure system prevalent in the project area in the baseline case is found elsewhere in the reference region.

  - **Land use:** Current and projected classes of land-use in the project area are found elsewhere in the reference region.

  - **Enforced policies and regulations**: The project area shall be governed by the same policies, legislation and regulations that apply elsewhere in the reference region.

1.1.2   Project area

The project area is the area or areas of land under the control of the project proponent on which the project proponent will undertake the project activities. At the project start date, the project area must include only forest land.

Any area affected by planned deforestation due to the construction of planned infrastructure (except if such planned infrastructure is a project activity) must be excluded from the project area.

The project area must include areas projected to be deforested in the baseline case and may include some other areas that are not threatened according to the first baseline assessment (see figure 1). Such areas will not generate carbon credits, but they may be included if the project proponent considers that future baseline assessments, which have to be carried out at least every 10 years, are likely to indicate that a future deforestation threat will exist, also the demonstration is not possible at the time of validation.

Where less than 80 percent of the total proposed area of the project is under control at validation, new discrete units of land may be integrated into an existing project area if included in the monitoring report at the time of the first verification. For the full rules and requirements regarding control over the entire project area at validation, please see the most recent version of the VCS AFOLU requirements.

The boundary of the project area shall be defined unambiguously as follows:

- Name (or names, as appropriate) of the project area.

- Physical boundary of each discrete area of land included in the project area (using appropriate GIS software formats).

- Description of current land-tenure and ownership, including any legal arrangement related to land ownership and the AUD project activity.

- List of the project participants and brief description of their roles in the proposed AUD project activity.

1.1.3   Leakage belt

If the project area is located within a jurisdictional program, leakage may not have be assessed and a leakage belt may not be required because any decrease in carbon stocks or increase in GHG emissions outside the project area would be measured, reported, verified and accounted under the jurisdictional program[12]. In such cases, the most recent VCS guidelines on this subject matter shall be applied. In all other cases, leakage is subject to MRV-A in an area called "leakage belt" in this methodology.

The leakage belt is the land area or land areas surrounding or adjacent to the project area in which baseline activities could be displaced due to the project activities implemented in the project area.

To define the boundary of the leakage belt, two methodological options can be used:

- Opportunity cost analysis (Option I); and

- Mobility analysis (Option II).

Under both options, the boundary of the leakage belt must be revisited at the end of each fixed baseline period, as opportunity costs and mobility parameters are likely to change over time. In addition, the boundary of the leakage belt may have to be revisited when other VCS-AFOLU projects are registered nearby the project area, as further explained below.

If mobility parameters or opportunity costs are projected for each future year, the boundary of the leakage belt that will remain static for the whole duration of the fixed baseline period shall be the one determined for the last year of the fixed baseline period.

Option I: Opportunity cost analysis

This option is applicable where economic profit is an important driver of deforestation. To demonstrate that Option I is applicable, use historical records, i.e. demonstrate that at least 80% of the area deforested in the reference region (or some of its strata) during the historical reference period[13] has occurred at locations where deforesting was profitable (i.e. for at least one product, $PPx_l \geq 1$). Alternatively, use literature studies, surveys and other credible and verifiable sources of information. If Option I is not applicable, use Option 2.

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[12]   In such cases, the sub-national or national government may define specific sub-national or national policies and regulations to deal with the issue of leakage.

[13]   See section 1.2.1 for the definition of "historical reference period."

If the main motivation is economic profit, agents not allowed to deforest within the project area will only displace deforestation outside the project area if doing so brings economic benefits to them. Based on this rationale leakage can only occur on land outside the project area where the total cost of establishing and growing crops or cattle and transporting the products to the market is less than the price of the products (i.e. opportunity costs are > 0).To identify this land area do the following:

a) List the main land-uses that deforestation agents are likely to implement within the project area in the baseline case, such as cattle ranching and/or different types of crops.

b) Find credible and verifiable sources of information on the following variables:

- $S\$x$ = Average selling price per ton of the main product Px (or product mixture in case of agro-forestry or mixed production systems) that would be established in the project area in the baseline case (meat, crop type A, crop type B, etc.);

- SPx_l = Most important selling points (spatial locations) for each main product Px in the reference region.

- PCx_i = Average *in situ* production costs per ton of product. Stratify the reference region as necessary in i strata, as production costs may vary depending on local conditions (soil, technology available to the producer, etc.).

- TC_v = Average transport cost per kilometer for one ton of product Px transported on different types of land-uses (e.g. pasture, cropland, forest), roads, railroads, navigable rivers, etc. using the most typical transport technology available to the producer.

Note: For simplicity, current prices and costs can be used to project opportunity costs. Price and cost projections shall only be used if reliable and verifiable sources of information are available.

c) Using a GIS, generate for each main product a surface representing the least transport cost of one ton of product to the most important selling points within the reference region. Do this by considering the most typical transport technology available to deforestation agents.

d) For each main product, add to the surface created in the previous step the average *in situ* cost for producing one ton of product. The result is a surface representing the total cost of producing and bringing to the market one ton of product.

e) For each main product, subtract from the average price of one ton of product the total cost surface created in the previous step. The result is a surface representing potential profitability of each product.

Note: If several products exist and can be produced on the same site, the maximum value of all potential profitability surfaces will represent the opportunity cost of conserving the forest.

f) The leakage belt is the area where the surface created in the previous step (potential profitability) has a positive value at the last year of the fixed baseline period.

The above methodology procedure can be summarized as follows:

A land unit (pixel or polygon l) is inside the leakage belt if the potential profitability of at least one product (PPx_l) is positive, where PPx_l is calculated as follows:

$$PPx_l = S\$x - PCx_i - \sum_{v=1}^{V}(TDv * TCv) \qquad (1)$$

Where:

PPx_l	Potential profitability of product Px at location l (pixel or polygon); \$/t
$S\$x$	Selling price of product Px; \$/t
PCx_i	Average *in situ* production costs for one ton of product Px in stratum i; \$/t
TCv	Average transport cost per kilometer for one ton of product Px on land, river or road of type v; \$/t/km
TDv	Transport distance on land, river or road of type v; km
v	1, 2, 3 ...V, type of surface to on which transport occurs; dimensionless

Note: Option I is based on the assumption that deforestation agents in the project area will not displace their activities beyond the reference region, where other forested areas with potentially positive opportunity costs may exist. Demonstrate that this assumption is credible using expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information. If the evidence collected is not convincing, use Option II (mobility analysis).

Option II: Mobility analysis

Mobility analysis can always be used but must be used where Option I is not applicable, i.e. when less than 80% of the area deforested in the reference region (or some of its strata) during the historical reference period has occurred at locations where deforesting was profitable. With this option, the potential mobility of deforestation agents is assessed using multi-criteria analysis. The following methodology steps shall be applied:

a) Using historical data, expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information list all relevant criteria that facilitate (at least one criterion) and constrain (at least one criterion) the mobility of the main deforestation agents identified in step 3. The overall suitability of the land for the activities of deforestation agents shall be considered and the selection of criteria must be consistent with criteria used to assess deforestation constraints in step 4.1.2.

b) For each criterion, generate a map using a GIS.

c) Using multi-criteria analysis, determine the boundary of the leakage belt. Justify any assumption and weight assigned to the individual criteria.

d) Methods used to perform the analysis shall be transparently documented and presented to VCS verifiers at the validation.

Consideration of other VCS AFOLU projects

If the leakage belt area of the proposed AUD project includes the area or part of the areas of other VCS AFOLU projects, do the following to avoid double counting of emissions:

- Exclude from the leakage belt area of the proposed AUD project the project area of the other VCS AFOLU project(s).

    a) The exclusion shall enter into force at the registration date of the other project

    b) Carbon accounting shall consider the exclusion of the project area of the other project beginning with the start date of the other projects

    c) An excluded area shall again be included in the leakage belt area of the proposed AUD project at the time the other project has not verified its emission reductions for more than five consecutive years, or when it ends its project crediting period under the VCS.

- It the leakage belt overlaps with the leakage belt of other VCS AFOLU projects, do the following:

    a) Identify the carbon pools and sources of GHG emissions that are monitored by the other projects. Only for common carbon pools and sources of GHG emissions the boundary of the leakage belt area can be modified as further explained below.

    b) Analyze the overlapping area(s) with the proponents of each of the other VCS AFOLU projects and come to an agreement with them on the location of the boundaries of the different leakage belts, so that there will be no overlaps and gaps between the different leakage belt areas as well as carbon pools and GHG sources.

    c) As an indicative rule, the percentage of forest land area within the leakage belt of a project relative to the total forest area of all leakage belts shall be similar to the percentage of baseline deforestation of the project relative to the total baseline deforestation of all projects:

$$\%LKBA = BLDA / (BLDA + BLDB + ... + BLDN) \qquad\qquad (2.a)$$

$$\%LKBB = BLDB / (BLDA + BLDB + ... + BLDN) \qquad\qquad (2.b)$$

$...$

$$\%LKBN = BLDN / (BLDA + BLDB + ... + BLDN) \qquad\qquad (2.n)$$

Where:

%LKBA   Percentage of the overlapping leakage belts area to be assigned to Project A; %

%LKBB   Percentage of the overlapping leakage belts area to be assigned to Project B; %

%LKBN   Percentage of the overlapping leakage belts area to be assigned to Project N; %

BLDA   Total area of projected baseline deforestation during the fixed baseline period of Project A (see PD of project A); ha

BLDB   Total area of projected baseline deforestation during the fixed baseline period of Project B (see PD of project B); ha

BLDN   Total area of projected baseline deforestation during the fixed baseline period of Project N (see PD of Project N); ha

Note: The proponents of the different projects shall agree on the criteria used to define the boundaries of their leakage belts in the overlapping areas and are not required to use the above rule. However, if they decide to use this rule, the area of the overlapping leakage belts assigned to Project A shall be the closest to the boundary of Project A; the area of the overlapping leakage belts assigned to Project B shall be the closest to the boundary of Project B and so on (the area of the overlapping leakage belts assigned to Project N shall be the closest to the boundary of Project N).

d) The final boundary of the leakage belt of each project is subject to validation and periodical verification. A project may report a smaller leakage belt only if another VCS registered project has included in its leakage belt the portion left out.

e) If the proponents of the different projects do not agree on how to split the overlapping leakage belt area, each project will have to include in its leakage belt the overlapping areas.

f) A "Leakage Belt Agreement" between the proponents of the different projects must be signed and presented to VCS verifiers at the time of validation/verification. The agreement shall contain the maps of the agreed leakage belts and each project shall have a digital copy of these maps in the projection and GIS software formats used in each project.

g) If a project ends or has not presented a verification to the VCS for more than five consecutive years, the other projects participating in the "leakage belt agreement" shall amend the agreement in order to ensure that the whole area of the originally overlapping leakage belts is always subject to MRV-A. The amendment is subject to VCS verification. If no amendment is made, the proposed project will have to include in its leakage belt the land area that is no longer be subject to MRV-A by a another VCS project.

1.1.4 Leakage management areas

These are non-forest areas located outside the project boundary in which the project proponent intends to implement activities that will reduce the risk of activity displacement leakage, such as afforestation, reforestation or enhanced crop and grazing land management. The boundary of such areas must be defined according to existing management plans or other plans related to the proposed AUD project activity. Such plans shall be made available to the VCS

Validation/Verification Body (VVB) at the time of validation. The boundary of leakage management areas must be clearly defined using the common projection and GIS software formats used in the project and shall be reassessed and validated at each fixed baseline period

1.1.5 Forest

The boundary of the forest is dynamic and will change over time. It must be defined using an explicit and consistent forest definition over different time periods.

In the baseline case, changes in the boundary of forest land will be projected, and the baseline projections must be reassessed at least every 10 years. In the project area and leakage belt, the *ex post* boundary of forest land will be subject to periodical monitoring, verification and reporting (MRV).

To define the boundary of the forest, specify:

- The definition of forest that will be used for measuring deforestation during the project crediting period (see appendix 1 for criteria to define "forest").

- The Minimum Mapping Unit (MMU). The MMU shall not be smaller than the minimum area threshold used in the definition of "forest".

An initial Forest Cover Benchmark Map is required to report only gross deforestation going forward. It should depict the locations where forest land exists at the project start date. The baseline projections in step 4.2 will generate one such map for each future year of the fixed baseline period and, optionally, project crediting period.

Areas covered by clouds or shadows should be analyzed by complementing the analysis of optical sensor data with non-optical sensor data. However, if some obscured areas remain for which no spatially explicit and verifiable information on forest cover can be found or collected (using ground-based or other methods), such areas shall be excluded (masked out). This exclusion would be:

- **Permanent**, unless it can reasonably be assumed that these areas are covered by forests (e.g. due to their location).

- **Temporal** in case information was available for the historical reference period, but not for a specific monitoring period. In this case, the area with no information must be excluded from the calculation of net anthropogenic GHG emission reductions of the current monitoring period, but not for subsequent periods, when information may become available again. When information becomes available again, and the land appears with vegetation parameters below the thresholds for defining "forest", the land should be considered as "deforested".

1.2 Temporal boundaries

Define the temporal boundaries listed below.

1.2.1 Starting date and end date of the historical reference period

The starting date should not be more than 10-15 years in the past and the end date as close as possible to the project start date. The project start date is the date at which the additional AUD project activities have or are to be started.

1.2.2 Starting date date of the project crediting period of the AUD project activity

The length of the project crediting period shall be established as set out on the most recent version of the VCS standard. .

1.2.3 Starting date and end date of the first fixed baseline period

The fixed baseline period shall be 10 years. The starting and end dates must be defined.

1.2.4 Monitoring period

The minimum duration of a monitoring period is one year and the maximum duration is one fixed baseline period.

1.3 Carbon pools

The six carbon pools listed in table 3 are considered in this methodology.

Table 3. **Carbon pools included or excluded within the boundary of the proposed AUD project activity**

Carbon pools	Included / TBD[1]/ Excluded	Justification / Explanation of choice
Above-ground	Tree: Included	Carbon stock change in this pool is always significant
	Non-tree: TBD	Must be included in categories with final land cover of perennial crop
Below-ground	TBD	Optional and recommended but not mandatory
Dead wood	TBD	
Harvested wood products	Included	To be included according to VCS Program Update of May 24th, 2010
Litter	N	Not to be measured according to VCS Program Update of May 24th, 2010
Soil organic carbon	TBD	Recommended when forests are converted to cropland. Not to be measured in conversions to pasture grasses and perennial crop according to VCS Program Update of May 24th, 2010.

1. TBD = To Be Decided by the project proponent. The pool can be excluded only when its exclusion does not lead to a significant over-estimation of the net anthropogenic GHG emission reductions of the AUD project activity.

2. The VCS defines as "significant" those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used[14].

- Carbon pools that are expected to decrease their carbon stocks in the project scenario compared to the baseline case must be included if the exclusion would lead to a significant overestimation of the net anthropogenic GHG emission reductions generated during the fixed baseline period.

- Carbon pools considered insignificant according to the latest VCS AFOLU requirements can always be neglected.

- Above-ground biomass of trees must always be selected because it is in this pool that the greatest carbon stock change will occur.

- Non-tree biomass must be included if the carbon stock in this pool is likely to be relatively large in the baseline compared to the project scenario such as when short-rotation woody corps are commonly planted in the region where the project area is located. The significance criterion shall apply.

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[14] Available at: http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

- Below-ground biomass of trees is recommended, as it usually represents between 15% and 30% of the above-ground biomass.

- Harvested wood products must be included if removal of timber is associated with significantly more carbon stored in long-term wood products in the baseline case compared to the project scenario. The significance criterion shall apply. When included, the carbon stock projected to accumulate in long-lived wood products in the baseline case must be subtracted from the total carbon stock of the forest existing prior to deforestation. In the project scenario, the carbon stock must be added.

- In most cases the exclusion of a carbon pool will be conservative, except when the carbon stock in the pool is higher in the baseline compared to the project scenario.

- The inclusion of a carbon pool is recommended (but not mandatory) where the pool is likely to represent an important proportion (> 10%) of the total carbon stock change attributable to the project activity ("expected magnitude of change").

- For excluded pools, briefly explain why the exclusion is conservative.

- When the exclusion of a carbon pool is not conservative, demonstrate that the exclusion will not lead to a significant overestimation of the net anthropogenic GHG emission reduction. If the exclusion is significant, the pool must be included.

- Carbon pools that are excluded or not significant according to the *ex ante* assessment do not need to be monitored *ex post*.

- In most cases the same carbon pools shall be considered for all categories of LU/LC change. However, including different carbon pools for different categories of LU/LC change is allowed depending on "significance", "conservativeness" and "expected magnitude of change". For instance, harvested wood products may only be considered in the categories where this pool exists.

- The final selection of carbon pools per category is done in step 2.3. Within a category of LU/LC-change, the same carbon pools must be selected for the two classes involved. Table 1 in appendix 2 provides an indication of the level of priority for including different carbon pools depending on the category of LU/LC change.

- If a pool is conservatively excluded at validation, project proponent cannot in subsequent monitoring and verification periods decide to measure, report and verify the excluded carbon pool. However, the reverse is possible i.e, if a pool is included at validation, it may be conservatively excluded in subsequent monitoring and verification periods provided all methodology requirements are applied to carry out the estimations and these are independently verified. Further guidance on the selection of carbon pools can be found in the most recent version of the GOFC-GOLD sourcebook for REDD[15] and further details are given in appendix 3.

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[15] GOFC-GOLD, 2010. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests and forestation. Available at: http://www.gofc-gold.uni-jena.de/redd/

1.4 Sources of GHG emissions

The two sources of GHG emissions listed in table 4 are considered in this methodology.

Table 4. Sources and GHG included or excluded within the boundary of the proposed AUD project activity

Sources	Gas	Included/TBD[1]/ excluded	Justification / Explanation of choice
Biomass burning	CO_2	Excluded	Counted as carbon stock change
	CH_4	TBD	See guidance below
	N_2O	Excluded	Considered insignificant according to VCS Program Update of May 24th, 2010
Livestock emissions	CO_2	Excluded	Not a significant source
	CH_4	TBD	See guidance below
	N_2O	TBD	See guidance below

1. TBD = To Be Decided by the project proponent. The source can be excluded only when its exclusion does not lead to a significant over-estimation of the net anthropogenic GHE emission reductions of the AUD project activity.

2. The VCS defines as "significant" those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used[16].

- Sources of emissions that are expected to increase in the project scenario compared to the baseline case must be included if the exclusion would lead to a significant overestimation of the total net anthropogenic GHG emission reductions generated during the fixed baseline period.

- Sources considered insignificant according to the latest VCS AFOLU requirements can always be neglected.

- The inclusion of a source is recommended (but not mandatory) where the source is likely to represent an important proportion (> 10%) of the total emissions reductions attributable to the project activity ("expected magnitude of change").

- The exclusion of a source is allowed only if the omission is conservative or the source is insignificant.

- Sources of GHG emissions that are not significant according to the *ex ante* assessment do not need not to be monitored *ex post*.

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[16] Available at: http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

- For excluded sources, briefly explain why the exclusion is conservative.

- In the baseline scenario: Non-CO_2 emissions from fires used to clear forests can be counted when sufficient data are available to estimate them. However, accounting for these emissions can conservatively be omitted. GHG emissions from land-uses implemented on deforested lands (including from biomass burning) are conservatively omitted in this methodology.

- In the project scenario: It is reasonable to assume that the project activity, including when harvest activities are planned (such as logging for timber, fuel-wood collection and charcoal production), produces less emissions of GHG than the baseline activities implemented prior and after deforestation on the deforested lands. Therefore, the omission of certain sources of GHG emissions, such as the consumption of fossil fuels, will not cause an overestimation of the net anthropogenic GHG emission reductions. However, non-CO_2 emissions from forest fires must be counted in the project scenario when they are significant.

- In the estimation of leakage: GHG emissions by sources that are attributable to leakage prevention measures (e.g. those implemented in leakage management areas) and that are increased compared to pre-existing GHG emissions count as leakage and should be estimated and counted if they are significant. Non-CO_2 emissions from displaced baseline activities, which are conservatively omitted in the baseline, can be ignored, as in the worst case scenario they would be similar to baseline emissions. However, if non-CO_2 emissions from forest fires used to clear forests are counted in the baseline, they must also be counted in the estimation of activity displacement leakage.

Step 2: Analysis of historical land-use and land-cover change

The goal of this step is to collect and analyze spatial data in order to identify current land-use and land-cover conditions and to analyze LU/LC change during the historical reference period within the reference region and project area. The tasks to be accomplished are the following:

2.1 Collection of appropriate data sources;

2.2 Definition of classes of land-use and land-cover;

2.3 Definition of categories of land-use and land-cover change;

2.4 Analysis of historical land-use and land-cover change;

2.5 Map accuracy assessment; and

2.6 Preparation of a methodology annex to the PD.

2.1 Collection of appropriate data sources

Collect the data that will be used to analyze land-use and land-cover change during the historical reference period within the reference region and project area. It is good practice to do this for at least three time points, about 3-5 years apart. For areas covered by intact forests,

it is sufficient to collect data for one single date, which must be as closest as possible to the project start date ($\leq$ 2 years).

As a minimum requirement:

- Collect medium resolution spatial data[17] (from 10m x 10m up to a maximum of 100m x 100m resolution) from optical and non-optical sensor systems, such as (but not limited to) Landsat[18], SPOT, ALOS, AVNIR2, ASTER, IRS sensor data) covering the past 10-15 years.

- Collect high resolution data from remote sensors (< 5 x 5 m pixels) and/or from direct field observations for ground-truth validation of the posterior analysis. Describe the type of data, coordinates and the sampling design used to collect them.

- In tabular format (table 5), provide the following information about the data collected:

Table 5. Data used for historical LU/LC change analysis

Vector (Satellite or airplane)	Sensor	Resolution		Coverage	Acquisition date	Scene or point identifier	
		Spatial	Spectral	(km^2)	(DD/MM/YY)	Path / Latitude	Row / Longitude

Where already interpreted data of adequate spatial and temporal resolution are available, with some caution[19] these can also be considered for posterior analysis.

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[17] 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 the latest version of the GOFC-GOLD sourcebook on REDD.

[18] On May 31, 2003, the scan-line-corrector (SLC) aboard Landsat 7 failed, producing horizontal zero-filled wedges in 22% of scenes from that point on. The nadir portion of full scene images is usually intact, though both east and west of nadir gaps extend to the scene edges. Gap-filling functions have been created, but algorithmic mechanisms that blur, average, or otherwise change spatial relationships between pixels spanning these gaps to existing pixels in the scene being filled are unsatisfactory from the perspective of the spatial modeling needs of REDD. Instead, users should fill in these gaps post-processing with spatially and spectrally satisfactory classifications from other sources (such as other complimentary optical and radar platforms).

[19] Existing maps should be used with caution because they often do not report documentation, error estimates, whether they were of the site or region in question or extracted from a national map, or whether they were obtained by change detection techniques rather than by static map comparison, etc. If data about historical LU/LC and/or LU/LC-change is already available, information about the minimum mapping unit, the methods used to produce these data, and descriptions of the LU/LC classes and/or LU/LC-change categories must be compiled, including on how these classes may match with IPCC classes and categories.

2.2 Definition of classes of land-use and land-cover

Identify and describe the land-use and land-cover (LU/LC) classes present in the reference region at the project start date. A LU/LC class is a unique combination of land-use and land-cover for which:

a) The boundary can be defined at hand of remotely sensed data and/or other sources of information, such as maps of vegetation, soil, elevation, management category, etc., as defined by the project proponent to unambiguously define a LU/LC class; and

b) Carbon stocks per hectare (tCO_2-e ha^{-1})[20] within each class are about homogeneous across the landscape. Carbon stocks must only be estimated for classes inside the project area, leakage belt and leakage management areas, which will be done in step 6.

The following criteria shall be used to define the LU/LC classes:

- The minimum classes shall be "Forest Land" and "Non-Forest Land".

- "Forest-land" will in most cases include strata with different carbon stocks. Forest-land must therefore be further stratified in forest classes having different average carbon densities within each class.

- "Non-Forest Land" may be further stratified in strata representing different non-forest classes. IPCC classes used for national GHG inventories may be used to define such classes (Crop Land, Grass Land, Wetlands, Settlements, and Other Land). See IPCC 2006 GL AFOLU Chapter 3, Section 3.2, p. 3.5 for a description of these classes. However, where appropriate to increase the accuracy of carbon stock estimates, additional or different sub-classes may be defined.

- The description of a LU/LC class must include criteria and thresholds that are relevant for the discrimination of that class from all other classes. Select criteria and thresholds allowing a transparent definition of the boundaries of the LU/LC polygons of each class. Such criteria may include spectral definitions as well as other criteria used in post-processing of image data, such as elevation above sea level, aspect, soil type, distance to roads[21] and existing vegetation maps. Where needed, in the column "description" of table 6 refer to more detailed descriptions in the methodological annex to be prepared in step 2.6.

- For all forest classes present in the project area, specify whether logging for timber, fuel wood collection or charcoal production are happening in the baseline case. If different combinations of classes and baseline activities are present in the project area,

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[20] The carbon stock per hectare is sometimes referred to as "carbon density" in the literature.

[21] Some classes may be defined using indirect criteria (e.g. "Intact old-growth forest" = Forest at more than 500 m from the nearest road; "Degraded forest" = Forest within 500 m from the nearest road. In this example, the assumption is made that logging activities usually do not occur, or are of very low intensity, when the trees are at more than 500 m from the nearest road). The use of indirect criteria shall be briefly justified in the PD at hand of verifiable information, such as independent studies, literature, etc. Using a definition of "degraded forest" as in this example, the boundary of the polygon class "degraded forest" would be a function of how the road network develops over time, which implies that such development will have to be monitored.

define different classes for each combination, even if carbon stocks are similar at the project start date.

- If a forest class has predictably growing carbon stocks (i.e. the class is a secondary forest) and the class is located both in the project area and leakage belt, two different classes must be defined (see step 6.1 for explanations).

- In most cases one single <u>Land-Use and Land-Cover Map</u> representing the spatial distribution of forest classes at the project start date will be sufficient. However, where certain areas of land are expected to undergo significant changes in carbon stock due to growth or degradation in the baseline case, a sequence of <u>Land-Use and Land-Cover Maps</u> representing the mosaic of forest-classes of each future year may be generated.

- The generation of such a sequence of maps is mandatory only for areas within the project boundary that are undergoing degradation in the baseline case, i.e. categories C, D, E and/or F are present in the project area (see table 1 and figure 2).

- Any assumption on changing carbon stocks in the baseline case must be documented at hand of credible and verifiable sources of information, such as measurements in plots representing a chrono-sequence, published literature, and other sources, as appropriate.

- List the resulting final LU/LC-classes in table 6.

Table 6. List of all land use and land cover classes existing at the project start date within the reference region

Class Identifier		Trend in Carbon stock[1]	Presence in[2]	Baseline activity[3]			Description (including criteria for unambiguous boundary definition)
ID_{cl}	Name			LG	FW	CP	
1							
2							
…							
Cl							

1. Note if "decreasing", "constant", "increasing"

2. RR = Reference region, LK = Leakage belt, LM = Leakage management Areas, PA = Project area

3. LG = Logging, FW = Fuel-wood collection; CP = Charcoal Production (yes/no)

4. Each class shall have a unique identifier (ID_{cl}). The methodology sometimes uses the notation icl (= 1, 2, 3, … Icl) to indicate "initial" (pre-deforestation) classes, which are all forest classes; and fcl (= 1, 2, 3, … Fcl) to indicate final" (post-deforestation) classes. In this table all classes ("initial" and "final") shall be listed.

2.3 Definition of categories of land-use and land-cover change

Identify all LU/LC-change categories that could occur within the project area and leakage belt during the project crediting period in both, the baseline and project case. This can be done by analyzing a land-use change matrix that combines all LU/LC-classes previously defined.

List the resulting LU/LC-change categories in table 7.a and 7.b:

Table 7.a. Potential land-use and land-cover change matrix

			Initial LU/LC class		
	ID_{cl}	I1	I2	I...	In
Final LU/LC class	F1	I1/F1	I2/F1	I.../F1	In/F1
	F2	I1/F2	I2/F2	I.../F2	In/F2
	F...	I1/F...	I2/F...	I.../F3	In/F...
	Fn	I1/Fn	I2/Fn	I.../Fn	In/Fn

Table 7.b. List of land-use and land-cover change categories

ID_{ct}	Name	Trend in Carbon stock	Presence in	Activity in the baseline case			Name	Trend in Carbon stock	Presence in	Activity in the project case		
				LG	FW	CP				LG	FW	CP
I1/F1												
I1/F2												
I1/F...												
I2/F1												
I2/F2												
I2/F...												
I.../F1												
I.../F2												
I.../F...												

2.4   Analysis of historical land-use and land-cover change

Using the data collected in step 2.1, divide the reference region in polygons[22] representing the LU/LC-classes and LU/LC-change categories defined in steps 2.2 and 2.3. In the case of the project area, LU/LC-change analysis is required to exclude any area with forests that are less than 10 years old at the project start date.

Use existing LU/LC or LU/LC-change maps if the classes and categories are well described in these maps, so that they can be used for completing steps 2.2 and 2.3.

Where processed data of good quality are not available, unprocessed remotely sensed data must be analyzed to produce LU/LC maps and LU/LC-change maps. Given the heterogeneity of methods, data sources and image processing software, LU/LC-change detection should be performed by trained interpreters.

Typically, the analysis of LU/LC-change involves performing the following three tasks:

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[22]   Raster or grid data formats are allowed.

2.4.1   Pre-processing;

2.4.2   Interpretation and classification; and

2.4.3   Post-processing.

2.4.1 Pre-processing

Pre-processing typically includes:

a) <u>Geometric corrections</u> to ensure that images in a time series overlay properly to each other and to other GIS maps used in the analysis (i.e. for post-classification stratification). The average location error between two images should be < 1 pixel.

b) <u>Cloud and shadow removal</u> using additional sources of data (e.g. radar, aerial photographs, field-surveys).

c) <u>Radiometric corrections</u> may be necessary (depending on the change-detection technique used) to ensure that similar objects have the same spectral response in multi-temporal datasets.

d) <u>Reduction of haze</u>, as needed.

See the most recent version of the GOFC-GOLD sourcebook for REDD or consult experts and literature for further guidance on pre-processing techniques.

Duly record all pre-processing steps for later reporting.

2.4.2 Interpretation and classification

Two main categories of change detection exist and can be used (see IPCC 2006 GL AFOLU, Chapter 3A.2.4):

(1) <u>Post-classification change detection</u>: Two LU/LC maps are generated for two different time points and then compared to detect LU/LC changes. The techniques are straightforward but are also sensitive to inconsistencies in interpretation and classification of the LU/LC classes.

(2) <u>Pre-classification change detection</u>: These are more sophisticated approaches to LU/LC-change detection. They also require more pre-processing of the data (i.e. radiometric corrections). The basic approach is to compare by statistical methods the spectral response of the ground using two data sets acquired at different dates to detect the locations where a change has occurred and then to allocate different patterns of spectral change to specific LU/LC-change categories. This approach is less sensitive to interpretation inconsistencies but the methods involved are less straightforward and require access to the original unclassified remotely sensed data.

As several methods are available to derive LU/LC and LU/LC-change maps from multi-temporal data sets, the methodology does not prescribe any specific method. As a general guidance:

- Automated classification methods should be preferred because the interpretation is more efficient and repeatable than a visual interpretation.

- Independent interpretation of multi-temporal images should be avoided (but is not forbidden).

- Interpretation is usually more accurate when it focuses on change detection with interdependent assessment of two multi-temporal images together. A technique that may be effective is image segmentation followed by supervised object classification.

- Minimum mapping unit should be equal to or above the minimum area threshold used for defining "forest", but not above 5 times this value.

- See the most recent version of the GOFC-GOLD sourcebook on REDD or consult experts and literature for further guidance on methods to analyze LU/LC-change using remotely sensed data.

Duly record all interpretation and classification steps for later reporting.

2.4.3 Post-processing

Post-processing includes the use of non-spectral data to further stratify LU/LC-classes with heterogeneous carbon density in LU/LC classes with homogenous carbon density. Post-classification stratification can be performed efficiently using a Geographical Information System (GIS).

Current remote sensing technology is unable to discriminate carbon density classes, although some progress is being made using lidar and other technologies that combined with field-surveys can be used under this methodology. Some forest types (e.g. broadleaved forest, coniferous forests, mangroves) can be discriminated with high accuracy using remotely-sensed data only.

LU/LC-classes that cannot be stratified further using remote sensing techniques but that are likely to contain a broad range of carbon density classes should be stratified using:

- Biophysical criteria (e.g. climate or ecological zone, soil and vegetation type, elevation, rainfall, aspect, etc.)[23];

- Disturbance indicators (e.g. vicinity to roads; forestry concession areas; etc.); age (in cases of plantations and secondary forests);

- Land management categories (e.g. protected forest, indigenous reserve, etc.); and/or

- Other criteria relevant to distinguish carbon density classes.

See the most recent version of the GOFC-GOLD sourcebook for REDD and IPCC 2006 GL AFOLU for further guidance on stratification. The criteria finally used should be reported

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[23] IPCC 2006 Guidelines for National GHG Inventories provide default climate and soil classification schemes in Annex 3A.5 and guidance on stratifying LU/LC areas in Section 3.3.2.

transparently in the PD and referenced to in table 6. Some iteration between steps 2.2, 2.3, and 2.4.3 may be necessary.

Duly record all post-processing steps for later reporting.

At the end of step 2, the following products should be prepared for the reference region and project area:

a) A <u>Forest Cover Benchmark Map</u> for at least the most recent date (±2 years from the project start date) and 10 (± 2) years[24] prior to the project start date, showing only "forest" and "non-forest".

b) A <u>Land-Use and Land-Cover Map</u> for at least the most recent date (±2 years from the project start date) depicting the LU/LC-classes defined in step 2.2.

c) A <u>Deforestation Map</u> for each sub-period analyzed, depicting at least the category "deforestation". Many projects will have some level of no-data areas because of cloud-cover. In this case change rates should be calculated for each time step based only on areas that were not cloud-obscured in either date in question. Then, a maximum possible forest cover map should be made for the most recent year (±2 years from the project start date). The historical rate in % should be multiplied by the maximum forest cover area at the start of the period for estimating the total area of deforestation during the period.

d) A <u>Land-Use and Land-Cover Change Map</u> for at least the most recent period analyzed (3-5 years) depicting the LU/LC-change categories defined in step 2.3. In most cases, this map will be prepared by combining the Deforestation Map of the most recent period (3-5 years) with the most recent Land-Use and Land-Cover Map.

e) A <u>Land-Use and Land-Cover Change Matrix</u> for at least the most recent period analyzed, derived from the LU/LC-change map mentioned above, showing activity data for each LU/LC-change category. See appendix 2, table 4 for an example of a LU/LC change matrix.

2.5   Map accuracy assessment

A verifiable accuracy assessment of the maps produced in the previous step is necessary to produce a credible baseline[25].

The accuracy must be estimated on a class-by-class (LU/LC map) and category-by-category (LU/LC-change map) basis, respectively. A number of sample points on the map and their corresponding correct classification (as determined by ground-surveys or interpretation of higher resolution data as collected in step 2.1) can be used to create an error matrix with the diagonal showing the proportion of correct classification and the off-diagonal cells showing the relative proportion of misclassification of each class or category into the other class or,

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[24]   This is to exclude from the project area forests that are less than 10 years old at the project start date.

[25]   See Chapter 5 of IPCC 2003 GPG, Chapter 3A.2.4 of IPPC 2006 Guidelines for AFOLU, and the most recent version of the GOFC-GOLD Sourcebook on REDD for guidance on map accuracy assessment.

respectively, categories. Based on the error matrix (also called confusion matrix), a number of accuracy indices can be derived (see e.g. Congalton, 1991 and Pontius, 2000).

The minimum overall accuracy of the Forest Cover Benchmark Map should be 90%.

The minimum classification accuracy of each class or category in the Land-Use and Land-Cover Map and Land-Use and Land-Cover Change Map, respectively, should be 80%. If the classification of a class or category is lower than 80%:

- Consider merging the class/category with other classes/categories[26]; or

- Exclude from the <u>Forest Cover Benchmark Map</u> the forest-classes that are causing the greatest confusion with non-forest classes according to the error matrix (e.g. initial secondary succession and heavily degraded forest may be difficult to distinguish from certain types of grassland or cropland, such as agro-forestry and silvo-pastoral systems not meeting the definition of "forest"). This implies conservatively reducing the area of the <u>Forest Cover Benchmark Map</u>.

- Both commission errors (false detection of a class/category, such as "deforestation") and omission errors (non-detection of actual class/category, such as "deforestation") should be estimated and reported.

- If ground-truthing data are not available for time periods in the past, the accuracy can be assessed only at the most recent date, for which ground-truthing data can be collected.

Where the assessment of map accuracy requires merging or eliminating classes or categories to achieve the required map accuracy, the definitions in the previous sub-steps must be adjusted accordingly. The final maps and the class/category definitions must be consistent.

2.6   Preparation of a methodology annex to the PD

LU/LC-change analysis is an evolving field and will be performed several times during the project crediting period. A consistent time-series of LU/LC-change data must emerge from this process.

In general, the same source of remotely sensed data and data analysis techniques must be used within a period for which the baseline is fixed (fixed baseline period). However, if remotely sensed data have become available from new and higher resolution sources (e.g. from a different sensor system) during this period, these can only be used if the images based on interpretation of the new data overlap the images based on interpretation of the old data by at least 1 year and they cross calibrate to acceptable levels based on commonly used methods in the remote sensing community.

To achieve a consistent time-series, the risk of introducing artifacts from method change must be minimized. For this reason, the detailed methodological procedures used in pre-processing,

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[26]   The tradeoff of merging classes or categories is that carbon estimates will be subject to a higher degree of variability.

classification, post classification processing, and accuracy assessment of the remotely sensed data, must be carefully documented in an <u>Annex to the PD</u>. In particular, the following information must be documented:

a) <u>Data sources and pre-processing</u>: Type, resolution, source and acquisition date of the remotely sensed data (and other data) used; geometric, radiometric and other corrections performed, if any; spectral bands and indexes used (such as NDVI); projection and parameters used to geo-reference the images; error estimate of the geometric correction; software and software version used to perform pre-processing tasks; etc.

b) <u>Data classification and post-processing</u>: Definition of the LU/LC classes and LU/LC-change categories; classification approach and classification algorithms; coordinates and description of the ground-truthing data collected for training purposes; ancillary data used in the classification, if any; software and software version used to perform the classification; additional spatial data and analysis used for post-classification analysis, including class subdivisions using non-spectral criteria, if any; etc.

c) <u>Classification accuracy assessment:</u> Accuracy assessment technique used; coordinates and description of the ground-truth data collected for classification accuracy assessment; post-processing decisions made based on the preliminary classification accuracy assessment, if any; and final classification accuracy assessment.

Step 3: Analysis of agents, drivers and underlying causes of deforestation and their likely future development

Understanding "who" is deforesting the forest (the "agent") and what drives land-use decisions ("drivers" and "underlying causes") is necessary for two mains reasons: (i) Estimating the quantity and location of future deforestation; and (ii) Designing effective measures to address deforestation, including leakage prevention measures.

This analysis is performed through the following five sub-steps[27]:

3.1   Identification of agents of deforestation;

3.2   Identification of deforestation drivers;

3.3   Identification of underlying causes;

3.4   Analysis of chain of events leading to deforestation; and

3.5   Conclusion

3.1   Identification of agents of deforestation

Identify the <u>main agent groups</u> of deforestation (farmers, ranchers, loggers, etc.) and their <u>relative importance</u> (i.e. the amount of historical LU/LC-change that can be attributed to each

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[27]   See Angelsen and Kaimowitz (1999) and Chomiz *et al*. (2006) for comprehensive analysis of deforestation agents and drivers.

of them). To do this identification, use existing studies, the maps prepared in step 2, expert-consultations, field-surveys and other verifiable sources of information, as needed.

Sometimes, the relative importance of each agent can be determined from the LU/LC-change matrix developed in step 2.4, since each agent usually converts forests for a specific purpose (cattle ranching, cash-crop production, subsistence farming, etc.).

If the relative importance of different agents is spatially correlated (e.g. small farmers are concentrated in the hills, while ranchers on the planes) it may be useful to stratify the reference region, the project area and the leakage belt accordingly (in I_{RR} strata), and to continue the baseline assessment for each stratum i separately in order to increase the accuracy of the projections.

For each identified agent group, provide the following information:

a) Name of the main agent group or agent;

b) Brief description of the main social, economic, cultural and other relevant features of each main agent group. Limit the description to aspects that are relevant to understand why the agent group is deforesting;

c) Brief assessment of the most likely development of the population size of the identified main agent groups in the reference region, project area and leakage belt.

d) Statistics on historical deforestation attributable to each main agent group in the reference region, project area and leakage belt.

3.2   Identification of deforestation drivers

For each identified agent group, analyze factors that drive their land-use decisions. The goal is to identify the immediate causes of deforestation.

Two sets of driver variables have to be distinguished:

a)   Driver variables explaining the quantity (hectares) of deforestation (to be used in step 4.1 and 4.3, as appropriate), such as:

- Prices of agricultural products;

- Costs of agricultural inputs;

- Population density;

- Rural wages;

- Etc.

b)   Driver variables explaining the location of deforestation, also called "predisposing factors" (de Jong, 2007) (to be used in step 4.2), such as:

- Access to forests (such as vicinity to existing roads, railroads, navigable rivers and coastal lines);

- Slope;

- Proximity to markets;

- Proximity to existing or industrial facilities (e.g. sawmills, pulp and paper mills, agricultural products processing facilities, etc.);

- Proximity to forest edges;

- Proximity to existing settlements;

- Spatial variables indicating availability within the forest of land with good ecological conditions to expand agricultural activities, such as soil fertility and rainfall;

- Management category of the land (e.g. national park, indigenous reserve, etc.);

- Etc.

For each of these two sets of variables:

1) List the 1 to 5 key driver variables and provide any relevant source of information that provides evidence that the identified variables have been a driver for deforestation during the historical reference period.

2) Briefly describe for each main agent group identified in step 3.1 how the key driver variables have and will most likely impact on each agent group's decision to deforest.

3) For each identified key driver variable provide information about its likely future development[28], by providing any relevant source of information.

4) For each identified driver variable briefly describe the project measures that will be implemented to address them[33], if applicable.

3.3   Identification of underlying causes of deforestation

The agents' characteristics and decisions are themselves determined by broader forces, the underlying causes of deforestation, such as:

- Land-use policies and their enforcement;

- Population pressure;

- Poverty and wealth;

- War and other types of conflicts;

- Property regime;

- Etc.

1) List the 1 to 5 key underlying causes and cite any relevant source of information that provides evidence that the identified variables have been an underlying cause for deforestation during the historical reference period.

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[28]   This does not apply to spatial variables, such slope, elevation etc.

2)   <u>Briefly describe</u> how each key underlying cause has determined and will most likely determine the key drivers identified in step 3.2 and the decisions of the main agent groups identified in step 3.1.

3)   For each identified key underlying cause provide information about its <u>likely future development</u>, by citing any relevant source of information.

4)   For each identified underlying cause describe the <u>project measures</u> that will be implemented to address them, if applicable.

3.4   Analysis of chain of events leading to deforestation

Based on the historical evidence collected, analyze the relations between main agent groups, key drivers and underlying causes and explain the sequence of events that typically has lead and most likely will lead to deforestation. Consult local experts, literature and other sources of information, as necessary. Briefly summarize the results of this analysis in the PD.

3.5   Conclusion

The analysis of step 3 must conclude with a statement about whether the available evidence about the most likely future deforestation trend within the reference region and project area is:

- Inconclusive or
- Conclusive.

"Conclusive" evidence in this methodology means that the hypothesized relationships between agent groups, driver variables, underlying causes and historical levels of deforestation can be verified at hand of statistical tests, literature studies, or other verifiable sources of information, such as documented information provided by local experts, communities, deforestation agents and other groups with good knowledge about the project area and the reference region.

To arrive at an overall "conclusive" conclusion when multiple agents and drivers are present, the evidence obtained for each of them must lead to a "conclusive" decision for all.

<u>When the evidence is conclusive</u>, state whether the weight of the available evidence suggests that the overall trend in future baseline deforestation rates will be:

- Decreasing;
- About constant;
- Increasing.

Then proceed to step 4.

<u>When the evidence is inconclusive</u> and the historical deforestation trend has been decreasing or about constant, additional analysis must be carried out under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until conclusive evidence on the most likely future deforestation trend is found, otherwise it will

not be possible to continue with the next steps of the methodology. If the historical deforestation trend has been increasing and the evidence is inconclusive, the deforestation rate to be used in the projections will be the average historical rate (see step 4.1.1). Alternatively, additional analysis could be carried out under step 3 until finding conclusive evidence.

Where different strata have been considered in the analysis, a conclusion and statement of trend is needed for each stratum. For a conservative baseline projection, the project proponent shall consider that in all the scenarios the agents and drivers of the deforestation activities are realistic and conservative, based on published and reliable data, and consistent with existing concrete actions and enforced laws avoiding deforestation, such as effective surveillance and law enforcement.

Step 4: Projection of future deforestation

This step is the core of the baseline methodology. Its objective is to locate in space and time the baseline deforestation expected to occur within the reference region during the first fixed baseline period and, optionally, the project crediting period.

Where a baseline has already been defined for a geographic area that includes the project area and its leakage belt and this baseline is applicable according to the most recent VCS requirements on regional baselines or the criteria specified in table 2, the existing baseline must be used and the methodology continues with step 5.

4.1 Projection of the quantity of future deforestation

This sub-step is to determine the quantity of baseline deforestation (in hectares) for each future year within the reference region.

Where appropriate, the reference region can be stratified according to the findings of step 3 and different deforestation rates be estimated for each stratum[29]. If the reference region is stratified, the rationale for the stratification must be explained and a map of the strata provided. Briefly summarize the stratification criteria, and the strata using table 8:

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[29]   Strata may be static (with fixed boundaries) or dynamic (with boundaries shifting over time).

Table 8. Stratification of the reference region

Stratum ID		Description	Area at year[1]			
			1	2	…	T
ID_i	Name		ha	ha	ha	ha
1						
2						
..						
n						
I_{RR}						

1. If the boundary of the strata is dynamic, explain the rationale and provide the estimated annual area of each stratum in the table.

If a jurisdiction (national or sub-national government) has adopted a VCS or UNFCCC registered (and VCS endorsed) baseline deforestation rate that is applicable to the reference region, project area and leakage belt according to the most recent VCS requirements on regional/jurisdictional baselines, the adopted rate must be used and no further analysis is required under this sub-step (continue with step 4.2).

Where the above condition does not exist, a projected deforestation rate must be determined by the project proponent taking into account possible future changes at the level of agents, drivers and underlying causes of deforestation, as well as the remaining forest area that is potentially available for conversion to non-forest uses. This task is performed through the following three analytical sub-steps:

    4.1.1   Selection of the baseline approach;

    4.1.2   Analysis of constraints to the further expansion of the deforestation;

    4.1.3   Quantitative projection of future deforestation.

4.1.1 Selection of the baseline approach

To project future deforestation three baseline approaches are available:

    a) <u>Historical average approach</u>: Under this approach, the rate of baseline deforestation is assumed to be a continuation of the average annual rate measured during the historical reference period within the reference region or, where appropriate, within different strata of the reference region.

    b) <u>Time function approach</u>: With this approach, the rate of baseline deforestation is estimated by extrapolating the historical trend observed within the reference region (or its strata) as a function of time using either linear regression, logistic regression or any other statistically sound regression technique (see step 4.1.3). This approach requires multiple deforestation measurements during the past 10-15 years.

    c) <u>Modeling approach</u>: With this approach, the rate of baseline deforestation will be estimated using a model that expresses deforestation as a function of driver variables

selected by the project proponents. Such driver variables may be spatial and consistency with the analysis of step 3 must exist.

Select and justify the most appropriate baseline approach following the decision criteria described below. Different approaches can be used in different strata of the reference region, where appropriate.

1. The deforestation rates measured in different historical sub-periods in the reference region (or a stratum of it) do not reveal any trend (decreasing, constant or increasing deforestation) and:

   1.1　No conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence.

   1.2　Conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates: use approach "c" if there is at least one variable that can be used to project the deforestation rate, otherwise use approach "a".

2. The deforestation rates measured in different historical sub-periods in the reference region (or a stratum of it) reveal a clear trend and this trend is:

   2.1　A <u>decrease</u> of the deforestation rate and:

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend and making it likely that this trend will continue in the future: use approach "b".

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend and this evidence also suggest that the decreasing trend will change in the future due to predictable changes at the level of agents and drivers: use approach "c".

   - No conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence, then use approach "b".

   2.2　A <u>constant</u> deforestation rate and:

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend and making it likely that this trend will continue in the future: use approach "a".

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend and this evidence also suggests that the

historical trend will change in the future due to predictable changes at the level of agents and drivers: use approach "c".

- No conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence, then use approach "a".

    2.3   An <u>increase</u> of the deforestation rate and:

- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend and making it likely that this trend will continue in the future: use approach "b". If the future deforestation trend is likely to be higher than predicted with approach "b", use approach "c".

- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend but this evidence also suggests that the future trend will change: use approach "a" or develop a model (approach "c").

- No conclusive evidence emerges from the analysis of agents and drivers explaining the increasing trend: use approach "a".

4.1.2 Analysis of constraints to the further expansion of deforestation

Deforestation can only continue in the future if there are no constraints to the conversion of forest land to non-forest land. This is typically the case when the project area is located in a country or region with still significant forest cover (Olander *et al*., 2006).

To assess whether there is scarcity of forest land that is accessible to deforestation agents and potentially exposed to the risk of deforestation do the following:

1) <u>Identify land-use constraints</u>: Identify the biophysical constraints (soil, climate, elevation, slope etc. – as appropriate) and socio-economic constraints (mobility, land-use rights, areas with presence of conflicts and crime, etc. – as appropriate) that limit the geographical area where deforestation agents could expand their land-use activities in currently forested areas. Consider the constraints as they are perceived by the main groups of deforestation agents, taking into consideration their socio-economic conditions. To determine how constraints are perceived by the main groups of deforestation agents determine the threshold conditions under which they have deforested historically (e.g. range of slopes, types of soil, minimum/maximum rainfall, elevation range, etc. as relevant to determine the range where main types of crops and animals could survive). Use spatial data, literature, surveys, and/or rural participative appraisal (PRA) as appropriate.

2) <u>Estimate the remaining forest area that could be converted to non-forest land</u>: Using the constraints identified above, map the area currently covered by forests that is potentially available for the further expansion of non-forest uses in the reference

region (<u>Maximum Potential Deforestation Map</u>). Where the area that is available for conversion to non-forest uses is more than 100 times the average area annually deforested within the reference region during the historical reference period, conclude that there is no constraint to the continuation of deforestation and continue with step 4.1.3; otherwise continue with below (3).

3) <u>Stratify the "Maximum Potential Deforestation Map" in broad suitability classes</u>: Considering the constraints identified above, define criteria and thresholds that delineate "optimal", "average" and "sub-optimal"[30] conditions for each of the main land uses implemented by the main agent groups (e.g. by defining ranges of slope, rainfall, types of soils, etc. – as appropriate). Select thresholds that are relevant from the point of view of the deforestation agents. Using the selected criteria and thresholds stratify the "Maximum Potential Deforestation Map" in three broad suitability classes representing "optimal", "average" and "sub-optimal" areas for non-forest uses. When available from other sources, use existing maps.

4.1.3 Quantitative projection of future deforestation

The methodology procedure is to first project the annual areas or rates of baseline deforestation within the reference region (or – where appropriate – within different strata of the reference region), then to analyze the spatial location of these annual areas in the reference region (step 4.2), and finally, to determine the annual areas and location of deforestation in the project area and leakage belt.

4.1.3.1 Projection of the annual areas of baseline deforestation in the reference region

The method to be used depends on the baseline approach selected.

Approach "a": Historical average

The annual baseline deforestation area that applies at year t to stratum i within the reference region is calculated as follows:

$$ABSLRR_{i,t} = ARR_{i,t-1} * RBSLRR_{i,t} \tag{3}$$

Where:

$ABSLRR_{i,t}$ Annual area of baseline deforestation in stratum i within the reference region at year t; ha yr^{-1}

$ARR_{i,t-1}$ Area with forest cover in stratum i within the reference region at year t-1: ha

$RBSLRR_{i,t}$ Deforestation rate applicable to stratum i within the reference region at year t; %

t 1, 2, 3 ... T, a year of the proposed project crediting period; dimensionless

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[30] More or different "suitability classes" can be used, depending on the information that is available and the specific project circumstances.

i 1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless

Notes:

- During the first $Toptimal_i$ years, use $RBSLRR_{i,t} = RBSLRR\_opt_{i,t}$

- After $Toptimal_i$ years and for the following $Taverage_i$ years, use $RBSLRR_{i,t} = RBSLRR\_avg_{i,t}$

- After $Toptimal_i + Taverage_i$, use $RBSLRR_{i,t} = RBSLRR\_sopt_{i,t}$

- After $Toptimal_i + Taverage_i + Tsub\text{-}optimal_i$, use $RBSLRR_{i,t} = 0$

$$RBSLRR\_opt_{i,t} = \left(\frac{ARRoptimal_{i,t2}}{ARRloptimal_{i,t1}}\right)^{\frac{1}{t2-t1}} - 1 \tag{4.a}$$

$$RBSLRR\_avg_{i,t} = \left(\frac{ARRaverage_{i,t2}}{ARRaverage_{i,t1}}\right)^{\frac{1}{t2-t1}} - 1 \tag{4.b}$$

$$RBSLRR\_sopt_{i,t} = \left(\frac{ARRsub\_optimal_{i,t2}}{ARRsub\_optimal_{i,t1}}\right)^{\frac{1}{t2-t1}} - 1 \tag{4.c}$$

$Toptimal_i = Aoptimal_i / ABSLRRopt\_hrp_i$ (5.a)

$Taverage_i = Aaverage_i / ABSLRRavg\_hrp_i$ (5.b)

$Tsub\text{-}optimal_i = Asub\text{-}optimal_i / ABSLRRopt\_hrp_i$ (5.c)

Where:

$RBSLRR\_opt_{i,t}$ Deforestation rate[31] applicable to stratum i within the reference region at year t during the first $Toptimal_i$ years; %

$RBSLRR\_avg_{i,t}$ Deforestation rate applicable to stratum i within the reference region at year t after $Toptimal_i$ years and during $Taverage_i$ years; %

$RBSLRR\_sopt_{i,t}$ Deforestation rate applicable to stratum i within the reference region at year t after $Toptimal_i + Taverage_i$ and during $Tsub\text{-}optimal_i$ years; %

$ARR_{i,t1}$ Area with forest cover in stratum i on "optimal", "average" and "sub-optimal" areas at time $t1$; ha

$ARR_{i,t2}$ Area with forest cover in stratum i on "optimal", "average" and "sub-optimal" areas at time $t2$; ha

$ARRaverage_{i,t1}$ Area with forest cover in stratum i on "average" and "sub-optimal" areas at time $t1$; ha

$ARRaverage_{i,t2}$ Area with forest cover in stratum i on "average" and "sub-optimal" areas at time $t2$; ha

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[31]   See Puyravaud, J.-P., 2003. Standardizing the calculation of the annual rate of deforestation. Forest Ecology and Management, 177: 593-596

ARRsub_optimal$_{i,t1}$ Area with forest cover in stratum *i* on "sub-optimal" areas at time *t1*; ha

ARRsub_optimal$_{i,t2}$ Area with forest cover in stratum *i* on "sub-optimal" areas at time *t2*; ha

t1   Start date of the historical reference period; dimensionless

t2   End date of the historical reference period; dimensionless

ABSLRRopt_hrp$_i$ Average area deforested in *Aoptimal$_i$* during the historical reference period; ha

ABSLRRavg_hrp$_i$ Average area deforested in *Aaverage$_i$* during the historical reference period; ha

ABSLRRsopt_hrp$_i$ Average area deforested in *Asub-optimal$_i$* during the historical reference period; ha

ABSLRRavg_hrp$_i$ and *ABSLRRsopt_hrp$_i$* are calculated as follows:

$$ABSLRRopt\text{-}hrp_i = (Aoptimal_{i,t2} - Aoptimal_{i,t1}) / Thrp \tag{6.a}$$

$$ABSLRRavg\text{-}hrp_i = (Aaverage_{i,t2} - Aaverage_{i,t1}) / Thrp \tag{6.b}$$

$$ABSLRRsopt\text{-}hrp_i = (Asub\text{-}optimal_{i,t2} - Asub\text{-}optimal_{i,t1}) / Thrp \tag{6.c}$$

Where:

Aoptimal$_{i,t1}$ Area with forest cover in stratum *i* on "optimal areas at time *t1*; ha

Aoptimal$_{i,t2}$ Area with forest cover in stratum *i* on "optimal areas at time *t2*; ha

Aaverage$_{i,t1}$ Area with forest cover in stratum *i* on "average" areas at time *t1*; ha

Aaverage$_{i,t2}$ Area with forest cover in stratum *i* on "average" areas at time *t2*; ha

Asub-optimal$_{i,t1}$ Area with forest cover in stratum *i* on "sub-optimal" areas at time *t1*; ha

Asub-optimal$_{i,t2}$ Area with forest cover in stratum *i* on " "sub-optimal" areas at time *t2*; ha

Thrp   Duration of the historical reference period in years (= *t2 - t1*); yr

t   1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

i   1, 2, 3 ... *I$_{RR}$,* a stratum within the reference region; dimensionless

Approach "b": Time function

The annual area of baseline deforestation that applies at a year *t* to stratum *i* within the reference region during the first *Toptimal$_i$* years is calculated using one of the following equations:

- Linear regression: $ABSLRR_{i,t} = a + b*t$ (7.a)
- Logistic regression: $ABSLRR_{i,t} = ARR_i / (1+e^{-t})$ (7.b)

- Other types of regression: $ABSLRR_{i,t} = f(t)$ (7.c)

Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}
a	Estimated intercept of the regression line; ha yr^{-1}
b	Estimated coefficient of the time variable (or slope of the linear regression); ha yr^{-1}
e	Estimated parameter of the logistic regression
ARR_i	Total forest area in stratum i within the reference region at the project start date; ha
$f(t)$	A function of time
t	1, 2, 3 … T, a year of the proposed project crediting period; dimensionless
i	1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless

The model and its parameters are derived from data obtained from the historical reference period and are used to project future deforestation trends as shown in the figure 4 below.

Figure 4. Approach "b" for modeling $ABSLRR_i$
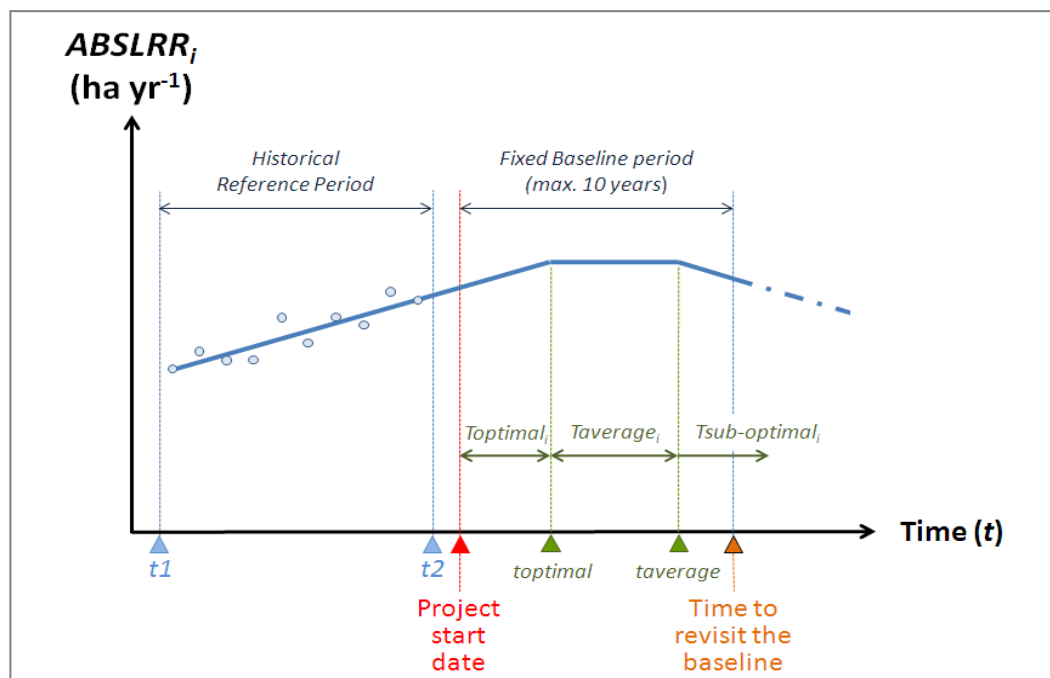
The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

When using equation 7.a (or any other model allowing an increase of the $ABSLRR_{i,t}$ as a function of time) $Toptimal_i$ must be calculated.

If: $b < 0$ → $Toptimal_i$ is the period of time during which equation 7.a yields a positive value. After that period of time, $ABSLRR_{i,t} = 0$.

If: $b > 0$ → $Toptimal_i$ is the period of time between $t = 1$ and $t = toptimal_i$, the latter being the year at which the following condition is satisfied:

$$Aoptimal_i = \sum_{t=1}^{toptimal_i} ABSLRR_{i,t} \qquad (8)$$

Where:

$Aoptimal_i$ Area of "optimal" forest land suitable for conversion to non-forest land within stratum i; ha

$ABSLRR_{i,t}$ Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}

t 1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

i 1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless

$toptimal_i$ Year at which $Toptimal_i$ ends; yr

If: $Toptimal_i \geq$ Project crediting period: $ABSLRR_{i,t}$ calculated with equation 7.a is applicable during the entire project crediting period.

If: $Toptimal_i <$ Project crediting period: $ABSLRR_{i,t}$ calculated with equation 7.a is applicable only to the first $Toptimal_i$ years. For the following $Taverage_i$ years use the following equation:

$$ABSLRR_{i,t} = a + b * toptimal_i \qquad (9)$$

Where:

$ABSLRR_{i,t}$ Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}

a Estimated intercept of the regression line; ha

b Estimated coefficient of the time variable; ha yr^{-1}

t 1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

i 1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless

$toptimal_i$ Year at which $Toptimal_i$ ends; yr

$Taverage_i$ is the period of time between $t = toptimal_i$ and $t = taverage_i$, the latter being the year at which the following condition is satisfied:

$$Aaverage_i = \sum_{t=toptimal_i}^{taverage_i} ABSLRR_{i,t} \hspace{4cm} (10)$$

Where:

$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum i; ha
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}
t	1, 2, 3 … T, a year of the proposed project crediting period; dimensionless
i	1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless
$toptimal_i$	Year at which $Toptimal_i$ ends; yr
$taverage_i$	Year at which $Taverage_i$ ends; yr

If: $Toptimal_i + Taverage_i \geq$ Project crediting period: $ABSLRR_{i,t}$ calculated with equation 9 is applicable during the period of time between $t = toptimal_i$ and $t = taverage_i$.

If: $Toptimal_i + Taverage_i <$ Project crediting period: $ABSLRR_{i,t}$ calculated with equation 9 is applicable only to the first $Taverage_i$ years following after year $toptimal_i$. For the following years use the following equation:

$$ABSLRR_{i,t} = ABSLRR_{taverage,i} - b * (t - taverage_i) \hspace{3cm} (11)$$

Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}
$ABSLRR_{taverage,i}$	Annual area of baseline deforestation in stratum i within the reference region at a year $taverage_i$; ha yr^{-1}
$taverage_i$	Year at which $Taverage_i$ ends; yr
t	1, 2, 3 … T, a year of the proposed project crediting period; dimensionless
i	1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless
a	Estimated intercept of the regression line; ha
b	Estimated coefficient of the time variable; ha yr^{-1}

Note: If $ABSLRR_{i,t}$ as calculated with equation 11 is < 0, use $ABSLRR_{i,t} = 0$.

Approach "c": Modeling

The annual area of baseline deforestation that applies at year t in stratum i within the reference region is estimated using a statistical model, such as simple regression, multiple regressions, logistic regression, or any other possible model to be proposed and justified by the project proponent. The proposed model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

The following equations are given for illustration purposes only:

$$ABSLRR_{i,t} = a + b1_i * V1_{i,t} \tag{12.a}$$

$$ABSLRR_{i,t} = a + b1_i * V1_{i,t} + b2_i * V2_{i,t} \tag{12.b}$$

$$ABSLRR_{i,t} = ARR_i / (1 + e^{-V1_{i,t}}) \tag{12.c}$$

Where:

$ABSLRR_{i,t}$ Annual area of baseline deforestation in stratum i within the reference region at a year t; ha yr^{-1}

$a; b1_i; b2_i; ... ; bn_i; e$ Estimated coefficients of the model

$V1_{i,t}; V2_{i,t}; ...; Vn_{i,t}$ Variables included in the model

ARR_i Total forest area in stratum i within the reference region at the project start date; ha

t 1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

i 1, 2, 3 ... I_{RR}, a stratum within the reference region; dimensionless

The model may also be constructed with the annual area deforested ($ABSLRR_{i,t}$), or the deforestation rate ($RBSLRR_{i,t}$ = percentage of remaining forest area at year $t-1$ in stratum i to be deforested at year t) as the dependent variable, and independent variable(s) (e.g. population density in stratum i at time t, average opportunity costs in stratum i at time t, etc.) from which the annual areas of deforestation ($ABSLRR_{i,t}$) or the deforestation rates ($RBSLRR_{i,t}$) are inferred from changes in the independent variables.

For each of the selected independent variables, there must be a description of the historical data (including source), an explanation of the rationale for using the variable(s), and a credible future projection based on documented and verifiable sources. To determine the future values of the variables included in the model, official projections, expert opinion, other models, and any other relevant and verifiable source of information must be used. Justify with logical and credible explanations any assumption about future trends of the driver variables and use values that yield conservative estimates of the projected deforestation ($ABSLRR_{i,t}$ or $RBSLRR_{i,t}$).

The model and its rationale must be explained by the project proponent using logical arguments and verifiable sources of information and must be consistent with the analysis of

step 3.The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

4.1.3.2 Projection of the annual areas of baseline deforestation in the project area and leakage belt

Location analysis of future deforestation within reference region is required to determine the annual areas of deforestation within the project area and leakage belt (step 4.2). Once location analysis is completed, the portion of annual areas of baseline deforestation of each stratum i within the project area and leakage belt must be determined using a GIS.

To do this step, step 4.2.4 must be completed first.

4.1.3.3 Summary of step 4.1.3

Present the results of the previous assessments in Tables 9.a and 9.b. Do this at least for the fixed baseline period and, optionally, for the entire project crediting period.

Table 9.a. Annual areas of baseline deforestation in the reference region

Project year t	Stratum i in the reference region				Total	
	1 $ABSLRR_{i,t}$ ha	2 $ABSLRR_{i,t}$ ha	… $ABSLRR_{i,t}$ ha	I_{RR} $ABSLRR_{i,t}$ ha	annual $ABSLRR_{t}$ ha	cumulative $ABSLRR$ ha
0						
1						
2						
. . .						
T						

Table 9.b. Annual areas of baseline deforestation in the project area

Project year t	Stratum i of the reference region in the project area				Total	
	1 $ABSLPA_{i,t}$ ha	2 $ABSLPA_{i,t}$ ha	… $ABSLPA_{i,t}$ ha	I_{RR} $ABSLPA_{i,t}$ ha	annual $ABSLPA_{t}$ ha	cumulative $ABSLPA$ ha
0						
1						
2						
. . .						
T						

Table 9.c. Annual areas of baseline deforestation in the leakage belt

| Project year t | Stratum i of the reference region in the leakage belt | | | | Total | |
	1 $ABSLLK_{i,t}$ ha	2 $ABSLLK_{i,t}$ ha	… $ABSLLK_{i,t}$ ha	I_{RR} $ABSLLK_{i,t}$ ha	annual $ABSLLK_t$ ha	cumulative $ABSLLK$ ha
0						
1						
2						
…						
T						

4.2   Projection of the location of future deforestation

Step 4.1 was to estimate the annual areas of baseline deforestation in the reference region. Step 4.2 is to analyze where future deforestation is most likely to happen in the baseline case in order to match the location of the projected deforestation with carbon stocks and determine the annual areas of baseline deforestation in the project area and leakage belt.

Step 4.2 is based on the assumption that deforestation is not a random event but a phenomenon that occurs at locations that have a combination of bio-geophysical and economic attributes that is particularly attractive to the agents of deforestation. For example, a forest located on fertile soil, flat land, and near to roads and markets for agricultural commodities is likely to be at greater risk of deforestation than a forest located on poor soil, steep slope, and far from roads and markets. Locations at higher risk are assumed to be deforested first. This hypothesis can be tested empirically by analyzing the spatial correlation between historical deforestation and geo-referenced bio-geophysical and economic variables. In the previous example, soil fertility, slope, distance to roads and distance to markets are the hypothesized spatial driver variables (SDV_i) or "predisposing factors" (De Jong, 2007). These variables can be represented in a map (or "Factor Map") and overlaid to a map showing historical deforestation using a Geographical Information System (GIS). From the combined spatial dataset information is extracted and analyzed statistically in order to produce a map that shows the level of deforestation risk at each spatial location ("pixel" or "grid cell"). The deforestation risk (or probability of deforestation) at a given spatial location changes at the time when one or more of the spatial driver variables change their values due to projected changes, e.g. when population density increases within a certain area, when a road is build nearby, or when areas recently deforested are coming closer, etc.

The basic tasks to perform the analysis described above are:

   4.2.1   Preparation of factor maps;

   4.2.2   Preparation of risk maps for deforestation;

   4.2.3   Selection of the most accurate deforestation risk map; and

4.2.4   Mapping of the locations of future deforestation.

Several model/software are available and can be used to perform these tasks in slightly different ways, such as Geomod, Idrisi Taiga, Dinamica Ego, Clue, and Land-Use Change Modeler. The model/software used must be peer-reviewed and must be consistent with the methodology (to be proven at validation).

4.2.1 Preparation of factor maps

Based on the analysis of step 3 and step 4.1, identify the spatial variables that most likely explain the patterns of baseline deforestation in the reference region. Obtain spatial data for each variable and create digital maps representing the <u>Spatial Features</u> of each variable (i.e. the shape files representing the point, lines or polygon features or the raster files representing surface features). Some models will require producing <u>Distance Maps</u> from the mapped features (e.g. distance to roads or distance to already deforested lands) or maps representing continuous variables (e.g. slope classes) and categorical variables (e.g. soil quality classes). If the model/software allows working with dynamic Distance Maps (i.e. the software can calculate a new Distance Maps at each time step), these should be used. For simplicity, these maps are called "<u>Factor Maps</u>". Other models do not require Factor Maps for each variable, and instead analyze all the variables and deforestation patterns together to produce a risk map.

Where some of the spatial variables are expected to change, collect information on the expected changes from credible and verifiable sources of information. Then prepare Factor Maps that represent the changes that will occur in different future periods. Sometimes, projected changes can be represented by a dynamic spatial model that may change in response to deforestation.

In case of planned infrastructure (e.g. roads, industrial facilities, settlements) provide documented evidence that the planned infrastructure will actually be constructed and the time table of the construction. In case of planned new roads, road improvements, or railroads provide credible and verifiable information on the planned construction of different segments (e.g. how many kilometers will be constructed, where and when). Evidence includes: approved plans and budgets for the construction, signed construction contracts or at least an open bidding process with approved budgets and finance. If such evidence is not available exclude the planned infrastructure from the factors considered in the analysis.

Any area affected by planned deforestation due to the construction of planned infrastructure must be excluded from the project area.

In case of unplanned infrastructure (e.g. secondary roads), provide evidence that the unplanned infrastructure will actually develop, e.g. from historical developments. Specifically, from a wall-to-wall assessment (or at least five randomly sampled observations in the reference region) or from literature sources appropriate to the reference region, estimate the average annual length[32] of new unplanned infrastructure per square kilometer[33] that was

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[32]   Other parameters relevant for modeling the construction of secondary roads may also be measured in this analysis, such as distance between roads, number of destinations per year, etc. Parameters to be assessed are

constructed during the historical reference period. Alternatively, determine the historical rate of change as related to variables for which there are good projections (e.g. km of new unplanned infrastructure as related to population). To avoid projecting unplanned infrastructure in areas where geographic and socio-economic conditions are unfavorable for infrastructure developments (e.g. areas with steep slopes, swampy soils, low opportunity costs, etc.), develop a map representing a proxy of the suitability for future infrastructure development. For each "suitability" class or gradient (using a minimum of two classes, e.g. suitable, not suitable), determine the most plausible rate of unplanned infrastructure development. To do this, apply the following steps:

a) Using historical data, expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information list all relevant criteria that facilitate (at least one criterion) and constrain (at least one criterion) the development of new unplanned infrastructure.

b) For each criterion, generate a map using a GIS.

c) Using multi-criteria analysis, determine the most likely rate of unplanned infrastructure development (e.g. km km^{-2} yr^{-1} or a similar indicator) per different sectors (suitability classes or gradients) within the reference region.

Projections of unplanned infrastructure development shall be conservative, in particular projections in forested areas shall meet this requirement.

To create the Factor Maps use one of the following two approaches:

- **Empirical approach:** Categorize each Distance Map in a number of predefined distance classes (e.g. class 1 = distance between 0 and 50 m; class 2 = distance between 50 and 100 m, etc.). In a table describe the rule used to build classes and the deforestation likelihood assigned to each distance class[34]. The deforestation likelihood is estimated as the percentage of pixels that were deforested during the period of analysis (i.e. the historical reference period).

- **Heuristic approach**: Define "value functions" representing the likelihood of deforestation as a function of distance from point features (e.g., saw mills) or linear features (e.g., roads), or as a function of polygon features representing classes (e.g. of soil type, population density) based on expert opinion or other sources of information. Specify and briefly explain each value function in the PD.

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dependent on the modeling approach used to project the development of the road network and are therefore not further specified here.

[33] Or per km of official new road constructed, or per other landscape features that can be mapped (such as new industrial facilities, settlements, mining concessions etc.), as appropriate.

[34] When building classes of continuous variables it is important to build classes that are meaningful in terms of deforestation risk. This implies the parameterization of a "value function" based on specific measurements. For instance, the criterion "distance to roads" might not have a linear response to assess the deforestation risk: a forest located at 50 km from the nearest road may be subject to the same deforestation risk of a forest located at 100 km, while at 0.5 km the risk may be twice as much as at 1.0 km. Data to model the value function and build meaningful classes can be obtained by analyzing the distribution of sample points taken from historically deforested areas.

For Distance Maps, a useful approach to estimate value functions is to sample spatially uncorrelated points and their corresponding location in the maps representing historical deforestation (<u>Land-Use and Land-Cover Change Maps</u> produced with step 2) and to use regression techniques[35] to define the probability of deforestation as a function of "distance".

The empirical approach should be preferred over the heuristic approach. Use the heuristic approach only where there is insufficient information about the spatial location of historical deforestation or where the empirical approach does not produce accurate results when validated against a historical period.

4.2.2 Preparation of deforestation risk maps

A <u>Risk Map</u> shows at each pixel location l the risk (or "probability") of deforestation in a numerical scale (e.g., 0 = minimum risk; 255 = maximum risk).

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 to the methodology at time of validation.

Several Risk Maps should be produced using different combinations of Factor Maps and modeling assumptions in order to allow comparison and select the most accurate map.

A list of Factor Maps, including the maps used to produce them and the corresponding sources shall be presented in the PD (table 10) together with a flow-chart diagram illustrating how the Risk Map is generated.

Table 10.   List of variables, maps and factor maps

Factor Map		Source	Variable represented		Meaning of the categories or pixel value		Other Maps and Variables used to create the Factor Map		Algorithm or Equation used	Comments
ID	File Name		Unit	Description	Range	Meaning	ID	File Name		

4.2.3 Selection of the most accurate deforestation risk map

Confirming the quality of 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. A good practice to confirm a model output (such as a risk map) is "calibration and

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35 e.g. logistic regression.

validation", referred to here as "calibration and confirmation" (so as not to be confused with validation as required by the VCS).

Two options are available to perform this task: (a) calibration and confirmation using two historical sub-periods; and (b) calibration and confirmation using tiles. Option (b) should be preferred where recent deforestation trends have been different from those in the more distant past.

a) Where two or more historical sub-periods have shown a similar deforestation trend, data from the most recent period can be used as the "confirmation" data set, and those from the previous period as the "calibration" data set.

Using only the data from the calibration period, prepare for each <u>Risk Map</u> a <u>Prediction Map</u> of the deforestation for the confirmation period. 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 <u>Risk Map</u> that was used to produce it. Prepare the final <u>Risk Map</u> using the data from the calibration and the confirmation period.

b) Where only one historical sub-period is representative of what is likely to happen in the future, divide the reference region in tiles and randomly select half of the tiles for the calibration data set and the other half for the confirmation set. Do the analysis explained above (see Castillo-Santiago *et al.,* 2007).

The Prediction Map with the best fit is the map that best reproduced actual deforestation in the confirmation period. The best fit must be assessed using appropriate statistical techniques. Most peer-reviewed modeling tools, such as Geomod, Idrisi Taiga, Land Use Change Modeler, and Dinamica Ego, include in the software package appropriate assessment techniques, which can be used under this methodology. Preference should be given to techniques that assess the accuracy of the prediction at the polygon level, such as the predicted quantity of total deforestation within the project area as compared to the observed one.

One of the assessment techniques that can be used is the "Figure of Merit" (*FOM*) that confirms the model prediction in statistical manner (Pontius *et al*. 2008; Pontius *et al*. 2007)[36].

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 (equation 13). The FOM ranges from 0.0, where there is no overlap between observed and predicted change, to 1.0 where there is a perfect overlap between observed and predicted

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[36] Pontius, R. G., 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. Pontius, R G, 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

change. The highest percent FOM must be used as the criterion for selecting the most accurate Deforestation Risk Map to be used for predicting future deforestation.

$$FOM = B / (A+B+C) \tag{13}$$

Where:

FOM   "Figure of Merit"; dimensionless

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

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

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

The minimum threshold for the best fit as measured by the Figure of Merit (*FOM*) must be more than 50%[37] for frontier landscape configuration and more than 80%[38] for mosaic landscape configuration. Where this minimum standard is not met, the project proponent must demonstrate that at least three models have been tested, and that the one with the best FOM is used.

4.2.4 Mapping of the locations of future deforestation

Future deforestation is assumed to happen first at the pixel locations with the highest deforestation risk value. To determine the locations of future deforestation do the following:

- In the most accurate Deforestation Risk Map select the pixels with the highest value of deforestation probability. Add the area of these pixels until their total area is equal to the area expected to be deforested in the reference region in project year one according to table 9.a. The result is the Map of Baseline Deforestation for Year 1.

- Repeat the above pixel selection procedure for each successive project year *t* to produce a series of Maps of Baseline Deforestation for each future project year. Do this at least for the upcoming fixed baseline period and, optionally, for the entire project crediting period.

- Add all yearly (baseline deforestation maps in one single map showing the expected Baseline Deforestation for the fixed baseline period and, optionally, for the entire project crediting period. Present this map in the PD.

The described pixel selection procedure and production of annual maps of baseline deforestation can be programmed in most state of the art modeling tools/software.

To obtain the annual areas of baseline deforestation within the project area, combine the annual maps of baseline deforestation for the reference region with a map depicting only the

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[37] Following Pontius et al. (2011), Pontius et al. (2008), and Pontius et al. (2007), in which it is shown that there is only one FOM greater than 50%.
[38]   These thresholds have been taken from the approved VCS Module VMD0007, Version 1.0.

polygon corresponding to the project area. After this step, table 9.b can be filled-out. The same must be done for the leakage belt area to fill-out table 9.c.

Step 5: Definition of the land-use and land-cover change component of the baseline

The goal of this step is to identify the forest classes that will be deforested and the non-forest classes that will replace them in the baseline case.

After step 4, the area and location of future deforestation are both known and pre-deforestation carbon stocks can be determined by matching the predicted location of deforestation with the location of forest classes with known carbon stocks.

Pre-deforestation carbon stocks shall be those existing or projected to exist at the year of the projected deforestation. This implies that forest classes in areas undergoing degradation in the baseline case will not be the ones existing at the project start date, but the ones projected to exist at the year of deforestation.

Post-deforestation carbon stocks can either be determined as the historical area-weighted average carbon stock, or using location analysis (modeling).

Apply the following sub-steps:

      5.1   Calculation of baseline activity data per forest class;

      5.2   Calculation of baseline activity data per post-deforestation class; and

      5.3   Calculation of baseline activity data per LU/LC change category.

Sub-step 5.3 applies only if the location of post-deforestation classes is known (i.e. the location of post-deforestation classes has been modeled).

5.1   Calculation of baseline activity data per forest class

Combine the Maps of Annual Baseline Deforestation of each future year produced in the previous step with the Land-Use and Land-Cover Map produced for the current situation in step 2 to produce a set of maps showing for each forest class the polygons that that would be deforested each year in absence of the AUD project activity. Extract from these maps the number of hectares of each forest class that would be deforested and present the results in table 11. Do this at least for the fixed baseline period and, optionally, for the project crediting period.

In most cases one single Land-Use and Land-Cover Map representing the spatial distribution of forest classes at the project start date will have been produced in step 2. However, where certain areas of land are expected to undergo significant changes in carbon stocks due to growth or degradation in the baseline case, a sequence of Land-Use and Land-Cover Maps representing the mosaic of forest-classes of each future year may have been generated in step 2, in which case it must be used this step.

Table 11. Annual areas deforested per forest class *icl* within the project area in the baseline case (baseline activity data per forest class)

	Area deforested per forest class *icl* within the project area				Total baseline deforestation in the project area	
IDicl>	1	2	…	*Icl*	*ABSLPA_t* annual	*ABSLPA* cumulative
Name >						
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Note: Forest classes shall be those projected to be present in *ABSLPAt* at year *t*.

5.2 Calculation of baseline activity data per post-deforestation forest class

Two methods are available to project the LU/LC classes that will replace forests in the baseline case; (1) "Historical LU/LC-change" and (2) "Modeling".

Method 1: Historical LU/LC-change

Historical LU/LC-changes are assumed to be representative for future trends. Hence, post-deforestation land-uses (non-forest classes) are allocated to the projected areas of annual deforestation in same proportions as those observed on lands deforested during the historical reference period.

Do the following calculations:

- Using the maps produced in step 2, calculate the area of each non-forest class on lands deforested during the historical reference period.

- Calculate the percentage of area of each non-forest class relative to the total area deforested during the historical reference period.

- Multiply the annual deforestation area calculated in table 9.b (for the project area) and table 9.c (for the leakage belt) by the percentage calculated for each non-forest class and report the result in table 12.b (for the project area) and 12.c (for the leakage belt). Do this at least for the fixed baseline period and, optionally, for the entire project crediting period. Doing the same for the reference region (table 12.a) is optional.

Table 12.a. **Annual areas of post-deforestation classes *fcl* within the reference region in the baseline case (baseline activity data per non-forest class)**

	Area established after deforestation per class *fcl* within the reference region				Total baseline deforestation in the reference region	
ID_{cl}	1	2	…	*Fcl*	$ABSLRR_t$ annual	*ABSLRR* cumulative
Name >						
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 12.b. **Annual areas of post-deforestation classes *fcl* within the project area in the baseline case (baseline activity data per non-forest class)**

	Area established after deforestation per class *fcl* within the project area				Total baseline deforestation in the project area	
ID_{cl}	1	2	…	*Fcl*	$ABSLPA_t$ annual	*ABSLPA* cumulative
Name >						
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 12.c. **Annual areas of post-deforestation classes *fcl* within the leakage belt in the baseline case (baseline activity data per non-forest class)**

	Area established after deforestation per class *fcl* within the leakage belt				Total baseline deforestation in the leakage belt	
ID_{cl}	1	2	…	*Fcl*	$ABSLLK_t$ annual	*ABSLLK* cumulative
Name >						
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Method 2: Modeling

The future spatial distribution of non-forest classes is determined using a spatial model. Two modeling techniques can be used:

a) Projection of LU/LC-change categories: Some deforestation modeling tools can be used to project several LU/LC-change categories at the same time, instead of just the broad category "deforestation". In such cases, the non-forest classes are determined by each projected category of change. Methods discussed in section 4.2.3 shall be used to select the most accurate prediction map.

b) Suitability modeling:

- Criteria must be identified determining the suitability of each main non-forest use, such as soil type, elevation, slope, etc. (as selected and justified by the project proponent).

- Using multi-criteria analysis the suitability of each non-forest class is determined for each spatial location. At each spatial location the class with the highest suitability value is assumed to be the one that deforestation agents will implement in absence of the AUD project activity.

- Show the results obtained in maps and summarize the results in tables 12.b and 12.c above (12.a is optional).

- The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

5.3   Calculation of baseline activity data per LU/LC change category

This sub-step is only applicable in conjunction with the Method 2 described above. The goal of this sub-step is to identify the categories of LU/LC-change and the level of activity data of each of these categories. This is performed as follows:

- Combine the maps showing the polygons of forest classes that would be deforested during each future year produced in step 4.2.4 with the map showing the non-forest LU/LC class prepared in step 5.2.

- From the combined datasets produce a new set of maps showing the polygons of the categories of LU/LC change for each future year. Some spatial modeling tools can produce these maps directly.

- Extract from the maps produced above the number of hectares (i.e., activity data) corresponding to each future year.

- Summarize the results in table 13.a (optional), 13.b and 13.c for the fixed baseline period and, optionally, for the project crediting period.

Table 13.a. Baseline activity data for LU/LC change categories (*ct*) in the reference region

Activity data per LU/LC category *ct* within the reference region				Total baseline deforestation in the reference region	
ID$_{ct}$	1	2	…	CT	
Name >				*ABSLRR$_t$* annual	*ABSLRR* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 13.b. Baseline activity data for LU/LC change categories (*ct*) in the project area

Activity data per LU/LC category *ct* within the project area				Total baseline deforestation in the project area	
ID$_{ct}$	1	2	…	CT	
Name >				*ABSLPA$_t$* annual	*ABSLPA* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 13.c. Baseline activity data for LU/LC change categories (*ct*) in the leakage belt

ID*ct*	1	2	…	CT	ABSLLK*t* annual	ABSLLK cumulative
Name >						
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Activity data per LU/LC category ct within the Leakage belt — *Total baseline deforestation in the leakage belt*

Step 6: Estimation of baseline carbon stock changes and non-CO₂ emissions

The goal of this step is to finalize the baseline assessment by calculating:

6.1   Baseline carbon stock changes; and (optionally)

6.2   Baseline non-CO₂ emissions from forest fires used to clear forests.

6.1   Estimation of baseline carbon stock changes

Before calculating the baseline carbon stock changes it is necessary to estimate the average carbon stock (tCO₂-e ha⁻¹) of each LU/LC class.

6.1.1 Estimation of the average carbon stocks of each LU/LC class

Average carbon stocks must be estimated only for:

- the forest classes existing within the project area[39];
- the forest classes existing within the leakage belt[40];
- the non-forest classes projected to exist in the project area in the baseline case;

[39] In most cases the forest classes existing within the project area at the project start date will remain the same in the baseline case. However, where certain areas within the project boundary are subject to baseline degradation due to unsustainable logging, fuel wood collection, charcoal production and other reasons, the decrease in carbon stocks must be projected. If carbon stocks are subject to enhancement, the projection is optional and can conservatively be omitted.

[40] In most cases the forest classes existing at the project start date within the leakage belt will remain the same in the baseline case. However, where certain areas within the leakage belt are subject to enhancement in the baseline case, carbon stocks must be projected for each year. If carbon stocks are subject to baseline degradation, projecting the changes in carbon stocks is optional and can conservatively be omitted.

- the non-forest classes projected to exist in the leakage belt in the project case; and

- the non-forest classes existing in leakage management areas.

Collect existing carbon-stock data for these classes from local published studies and existing forest and carbon inventories. Do additional field measurements for the classes for which there is insufficient information. Follow the guidance below:

a) Assess and, where appropriate, use existing data. It is likely that some existing data could be used to quantify the carbon stocks of one or more classes. These data could be derived from a forest inventory or perhaps from scientific studies. Analyze these data and use them if the following criteria are fulfilled:

- The data are less than 10 years old;

- The data are derived from multiple measurement plots;

- All species above a minimum diameter are included in the inventories;

- The minimum diameter for trees included is 30 cm or less at breast height (DBH);

- Data are sampled from good coverage of the classes over which they will be extrapolated.

Existing data that meet the above criteria shall only be applied across the classes from which they were representatively sampled and not beyond that. See the latest version of the GOFC-GOLD sourcebook on REDD and Gillespie, *et al.* (1992) for methods to analyze these data.

b) Collect missing data. For the classes for which no existing data are available it will be necessary to either obtain the data from field measurement or to use conservative estimates from the literature.

Field measurements:

- Locate the sampling sites. If the locations of future deforestation are known at the time of field measurements, the sample sites should be located at the locations expected to be deforested to achieve maximum accuracy of the carbon stock estimates.

- Design the sampling framework and conduct the field measurements following the guidance of appendix 3 (see also chapter 4.3 of GPG LULUCF and in the sourcebook for LULUCF by Pearson *et al*., 2005). Summarize the sampling design in the PD and provide a map and the coordinates of all sampled locations.

Literature estimates:

- The use of carbon stock estimates in similar ecosystems derived from local studies, literature and IPCC defaults is permitted[41], provided the accuracy and conservativeness of the estimates are demonstrated.

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[41] Attention must be paid on data units. In this methodology calculations are done in tCO_2-e while IPCC tables often provide data in tC (1 tC = 44/12 t CO_2-e)

- When defaults are used, the <u>lowest value</u> of the range given in the literature source (or the value reduced by 30%) must be used for the forest classes, and the <u>highest value</u> (or the value augmented by 30%) for non-forest classes.

c) <u>Forest classes in the project area</u>: prior to the year of baseline deforestation carbon stocks and boundaries of the forest-classes are assumed to remain the same, except in the following cases:

- If in the baseline case the forest within certain polygons of the project area is degrading and loosing carbon stocks, a map sequence showing the spatial and temporal sequence of forest classes with successively lower carbon stocks must be prepared to account for the degradation occurring prior to deforestation. To do the projection, use credible and verifiable sources of data from existing studies, or measure field plots in degraded forests of different known age.

- If in the baseline case the forest within certain polygons of the project area has increasing carbon stocks, changes in carbon stocks can conservatively be omitted and preparing a map sequence is optional for these polygons. If a projection is done, use credible and verifiable sources of data from existing studies, or measure field plots in secondary forests of different known age.

- If carbon stocks in the project area are decreasing more in the project case than in the baseline case (e.g. when the project activity involves logging for timber, fuel-wood collection or charcoal production in areas not subject to such activities in the baseline case), this will have to be accounted in the project case.

- If logging activities are present in the baseline, the harvested wood product carbon pool must be estimated and, if significantly higher in the baseline compared to the project scenario, it will have to be accounted.

d) <u>Forest classes in the leakage belt</u>: carbon stocks and boundaries of the forest-classes are assumed to remain the same, except in the following cases:

- If in the baseline case the forest within certain polygons of the leakage belt is growing and carbon stocks are increasing, a map sequence showing the spatial and temporal sequence of forest classes with successively higher carbon stocks must be prepared to account for the carbon stock enhancement. To do the projection, use credible and verifiable sources of data from existing studies, or measure field plots in secondary forests of different known age.

- If in the baseline case the forest within certain polygons of the leakage belt is degrading and loosing carbon stocks, changes in carbon stocks can conservatively be omitted and preparing a map sequence is optional for these polygons.

e) <u>Carbon stocks of post-deforestation classes</u> (non-forest classes) often do not have a stable carbon stock because different land uses may be implemented in a time sequence or because the land use established after deforestation implies carbon stocks changes

over time (e.g. in case of tree plantations[42]). The carbon stock of post-deforestation classes must be estimated as the long-term (20 year) average carbon stock and can be determined from measurements in plots of known age, long-term studies and other verifiable sources.

f)   Carbon stock estimates are subject to <u>uncertainty assessment</u> as indicated in appendix 2, Box 2. If the uncertainty of the total average carbon stock ($Ctot_{cl}$) of a class cl is less than 10% of the average value, the average carbon stock value can be used. If the uncertainty is higher than 10%, the lower boundary of the 90% confidence interval must be considered in the calculations if the class is an initial forest class in the project area or a final non-forest class in the leakage belt, and the higher boundary of the 90% confidence interval if the class is an initial forest class in the leakage belt or a final non-forest class in the project area.

The result of the estimations shall be presented in table 14.

6.1.2 Calculation of baseline carbon stock changes

The choice of the method to calculate carbon stock changes depends on whether activity data are available for classes or for categories.

<u>If activity data are available for classes (Method 1),</u> the total baseline carbon stock change in the project area at year t is calculated as follows:

$$\Delta CBSLPA_t = \sum_{icl=1}^{Icl} ABSLPA_{icl,t} * Ctot_{icl,t} - \sum_{fcl=1}^{Fcl} ABSLPA_{fcl,t} * Ctot_{fcl,t} \qquad (14)$$

Where:

$\Delta CBSLPA_t$ Total baseline carbon stock change within the project area at year t; tCO$_2$-e

$ABSLPA_{icl,t}$ Area of initial forest class icl deforested at time t within the project area in the baseline case; ha

$Ctot_{icl,t}$ Average carbon stock of all accounted carbon pools in the initial forest class icl at time t; tCO$_2$-e

Note: Letter "f" of the previous section applies.

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[42]   The IPCC methods for estimating the annual carbon stock change on forest land converted to non-forest land includes two components: (i) the initial change in carbon stocks due to the land conversion; and (ii) the gradual carbon loss (or gain) during a transition to a new steady-state system. Ignoring the second component can lead to an overestimation or to an underestimation of the baseline emissions, depending on land use and management after deforestation (which could range from forest plantations to progressive devegetation and soil degradation). Considering the second component would imply tracking annual carbon stock changes on deforested lands, which is unpractical and costly. To avoid these problems, the methodology estimates the average carbon density of each LU/LC-class established on deforested land within a pre-defined period of time. In this way, the first and second components are incorporated in the carbon stock change estimates without increasing complexity and monitoring costs.

$ABSLPA_{fcl,t}$ Area of the final non-forest class *fcl* at time *t* within the project area in the baseline case; ha

$Ctot_{fcl,t}$ Average carbon stock of all accounted carbon pools in non-forest class *fcl* at time *t*; tCO_2-e

Note: Letter "f" of the previous section applies.

icl   1, 2, 3 … *Icl* initial (pre-deforestation) forest classes; dimensionless

fcl   1, 2, 3 … *Fcl* final (post-deforestation) non-forest classes; dimensionless

t   1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

Use Tables 15.a – 15.c to report the result of the calculations.

Table 14. **Average carbon stock per hectare of all LU/LC classes present in the project area, leakage belt and leakage management area (The selection of carbon pools is subject to the latest VCS guidance on this matter, see table 3)**

LU/LC class		Average carbon stock per hectare $\pm$ 90% CI													
		Cab_{cl}		Cbb_{cl}		Cdw_{cl}		Cl_{cl}		$Csoc_{cl}$		Cwp_{cl}		$Ctot_{cl}$	
		average stock	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI	*average stock*	$\pm$ 90% CI
ID_{cl}	Name	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}	t CO$_2$e ha^{-1}
1															
2															
…															
Ncl															

Cab_{cl} Average carbon stock per hectare in the above-ground biomass carbon pool of class cl; tCO$_2$-e ha^{-1}

Cbb_{cl} Average carbon stock per hectare in the below-ground biomass carbon pool of class cl; tCO$_2$-e ha^{-1}

Cdw_{cl} Average carbon stock per hectare in the dead wood biomass carbon pool of class cl; tCO$_2$-e ha^{-1}

Cl_{cl} Average carbon stocker hectare in the litter carbon pool of class cl; tCO$_2$-e ha^{-1}

$Csoc_{cl}$ Average carbon stock in the soil organic carbon pool of class cl; tCO$_2$-e ha^{-1}

Cwp_{cl} Average carbon stocker hectare accumulated in the harvested wood products carbon pool between project start and the year of deforestation (stock remaining in wood products after 100 years)of class cl; tCO$_2$-e ha^{-1}

Note: In the baseline case, Cwp_{cl} must be subtracted from the sum of the other pools in the calculation of $Ctot_{cl}$

$Ctot_{cl}$ Average carbon stock per hectare n all accounted carbon pools cl; tCO$_2$-e ha^{-1}

Table 15.a. Baseline carbon stock change in pre-deforestation (forest) classes

Project year t	Carbon stock changes in initial (pre-deforestation) forest classes in the project area								Total carbon stock change in initial forest classes	
	$ID_{icl} = 1$		$ID_{icl} = 2$		$ID_{icl} = \ldots$		$ID_{icl} = Icl$		annual	cumulative
	$ABSLPA_{icl,t}$	$Ctot_{icl,t}$	$ABSLPA_{icl,t}$	$Ctot_{icl,t}$	$ABSLPA_{icl,t}$	$Ctot_{icl,t}$	$ABSLPA_{icl,t}$	$Ctot_{icl,t}$	$\Delta CBSLPAi_t$	$\Delta CBSLPAi$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
. . .										
T										

Table 15.b. Baseline carbon stock change in post-deforestation (non-forest) classes

Project year t	Carbon stock changes in final (post-deforestation) non-forest classes in the project area								Total carbon stock change in final non-forest classes	
	$ID_{fcl} = 1$		$ID_{fcl} = 2$		$ID_{fcl} = \ldots$		$ID_{fcl} = Fcl$		annual	cumulative
	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$\Delta CBSLPAf_t$	$\Delta CBSLPAf$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
. . .										
T										

Table 15.c. Total net baseline carbon stock change in the project area
(Calculated with Method 1: Activity data per class)

Project year t	Total carbon stock change in initial forest classes		Total carbon stock change in final non-forest classes		Total baseline carbon stock change in the project area	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLPAi_t$	$\Delta CBSLPAi$	$\Delta CBSLPAf_t$	$\Delta CBSLPAf$	$\Delta CBSLPA_t$	$\Delta CBSLPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0						
1						
. . .						
T						

If activity data are available for categories (Method 2), first calculate the carbon stock change factor ($\Delta Ctot_{ct,t}$)[43] of each category (also called "emission factor"), then calculate the total baseline carbon stock change in the project area at year t as follows:

$$\Delta CBSLPA_t = \sum_{ct=1}^{CT} ABSLPA_{ct,t} * \Delta Ctot_{ct,t} \qquad (15)$$

Where:

$\Delta CBSLPA_t$ Total baseline carbon stock change within the project area at year t; tCO$_2$-e

$ABSLPA_{ct,t}$ Area of category ct deforested at time t within the project area in the baseline case; ha

$\Delta Ctot_{ct,t}$ Carbon stock change factor for all accounted carbon pools in category ct at time t; tCO$_2$-e ha^{-1}

     Note: Carbon stock change factors are assumed not to change within a fixed baseline period

ct 1, 2, 3 … CT categories of LU/LC change; dimensionless

t 1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

Use table 16 to report the calculation of carbon stock change factors and table 17 to report total baseline carbon stock change in the project area.

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[43] The carbon stock change factor (or "emission factor") is the difference between the sums of the carbon stocks in the carbon pools accounted in the final class minus those accounted in the initial class.

Table 16. Carbon stock change factors per category of LU/LC change

Category from Table 7b		Average *carbon stock* ± 90% CI of the "initial" *class*																	Average *carbon stock* ± 90% CI of the "final" *class*																	Average *carbon stock change factor* ± 90% CI														
		Cab		*Cbb*		*Cdw*		*Cl*		*Csoc*		*Cwp*		*Ctot*		*Cab*		*Cbb*		*Cdw*		*Cl*		*Csoc*		*Cwp*		*Ctot*		□*Cab*		□*Cbb*		□*Cdw*		□*Cl*		□*Csoc*		□*Cwp*		□*Ctot*	
IDct	*Name*	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock	±90% CI	average stock change	±90% CI	average stock change	±90% CI	average stock change	±90% CI	average stock change	±90% CI	average stock change	±90% CI	average stock change	±90% CI	average stock change	±90% CI
		$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$
I1/F1																																											
I1/F2																																											
I1/F3																																											
I1/F4																																											
I2/F1																																											
I2/F2																																											
I2/F3																																											
I2/F4																																											
I3/F1																																											
I3/F2																																											

Table 17. **Total net baseline carbon stock change in the project area**
(Calculated with Method 2: Activity data per category)

Project year t	Activity data per category x Carbon stock change factor in the project area								Total baseline carbon stock change in the project area	
	$ID_{ct} = 1$		$ID_{ct} = 2$		$ID_{ct} = \ldots$		$ID_{ct} = Ict$		annual	cumulative
	$ABSLPA_{ct,t}$	$\Box Ctot_{ct,t}$	$ABSLPA_{ct,t}$	$\Box Ctot_{ct,t}$	$ABSLPA_{ct,t}$	$\Box Ctot_{ct,t}$	$ABSLPA_{ct,t}$	$\Box Ctot_{ct,t}$	$\Box CBSLPA_t$	$\Box CBSLPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

6.2 Baseline non-CO$_2$ emissions from forest fires

Emissions from fires used to clear forests in the baseline can always be omitted.

Conversion of forest to non-forest involving fires is a source of emissions of non-CO$_2$ gases (CH$_4$ and N$_2$O). When sufficient data on such forest fires are available from the historical reference period and the project proponent considers that these emissions are an important component of the baseline, CH$_4$ emissions from biomass burning can be estimated. Where such data are unavailable, or of insufficient accuracy, emissions from biomass burning should not be considered (which is conservative).

The effect of fire on carbon emissions is counted in the estimation of carbon stock changes; therefore CO$_2$ emissions from forest fires should be ignored to avoid double counting.

To estimate non-CO$_2$ emissions from forest fires, it is necessary to estimate the average percentage of the deforested area in which fire was used, the average proportion of mass burnt in each carbon pool ($Pburnt_{,p}$), and the average combustion efficiency of each pool (CE_p). These average percentage values are estimated for each forest class (icl) and are assumed to remain the same in the future.

Based on revised IPCC 1996 GL LULUCF, GHG emissions from biomass burning can be estimated as follows.

$$EBBtot_{icl,t} = EBBN2O_{icl,t} + EBBCH4_{icl,t} \qquad (16)$$

Where:

$EBBtot_{icl,t}$ Total GHG emission from biomass burning in forest class icl at year t; tCO$_2$-e ha^{-1}

$EBBN2O_{icl,t}$	N_2O emission from biomass burning in forest class icl at year t; tCO$_2$-e ha^{-1}
$EBBCH4_{icl,t}$	CH_4 emission from biomass burning in forest class icl at year t; tCO$_2$-e ha^{-1}

$$EBBN2O_{icl,t} = EBBCO2_{icl,t} * 12/44 * NCR*ER_{N2O}*44/28*GWP_{N2O} \qquad (17)$$

$$EBBCH4_{icl,t} = EBBCO2_{icl,t} * 12/44 * ER_{CH4}*16/12*GWP_{CH4} \qquad (18)$$

Where:[44]

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class icl at year t; tCO$_2$-e ha^{-1}
$EBBN2O_{icl,t}$	Per hectare N_2O emission from biomass burning in slash and burn in forest class icl at year t; tCO$_2$-e ha^{-1}
$EBBCH4_{icl,t}$	Per hectare CH_4 emission from biomass burning in slash and burn in forest class icl at year t; tCO$_2$-e ha^{-1}
NCR	Nitrogen to Carbon Ratio (IPCC default value = 0.01); dimensionless
ER_{N2O}	Emission ratio for N_2O (IPCC default value = 0.007)
ER_{CH4}	Emission ratio for CH_4 (IPCC default value = 0.012)
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period)

$$EBBCO2_{icl,t} = Fburnt_{icl} * \sum_{p=1}^{P}(C_{p,icl,t} * Pburnt_{p.icl} * CE_{p,icl}) \qquad (19)$$

Where:

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in the forest class icl at year t; tCO$_2$-e ha^{-1}
$Fburnt_{icl}$	Proportion of forest area burned during the historical reference period in the forest class icl; %
$C_{p,icl,t}$	Average *carbon stock* per hectare in the carbon pool p burnt in the forest class icl at year t; tCO$_2$-e ha^{-1}

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[44]   Refers to table 5.7 in 1996 Revised IPCC Guideline for LULUCF and equation 3.2.19 in IPCC GPG-LULUCF

$Pburnt_{p,icl}$ Average proportion of mass burnt in the carbon pool p in the forest class icl; %

$CE_{p,icl}$ Average combustion efficiency of the carbon pool p in the forest class icl; dimensionless

p Carbon pool that could burn (above-ground biomass, dead wood, litter)

icl 1, 2, 3, ...Icl (pre-deforestation) forest classes

t 1, 2, 3 … $T,$ a year of the proposed project crediting period; dimensionless

The combustion efficiencies may be chosen from table 3.A.14 of IPCC GPG LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used. The Nitrogen to Carbon Ratio (NCR) is approximated to be about 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available. Emission factors for use with above equations are provided in Tables 3.A 15 and 3.A.16 of IPCC GPG LULUCF.

Report the values of all estimated parameters in the following table.

Table 18. Parameters used to calculate non-CO$_2$ emissions from forest fires

Initial Forest Class		Parameters																
		$Fburnt_{icl}$	Cab	Cdw	Cl	$Pburnt_{ab,icl}$	$Pburnt_{dw,icl}$	$Pburnt_{l,icl}$	$CE_{ab,icl}$	$CE_{dw,icl}$	$CE_{l,icl}$	$ECO2\text{-}ab$	$ECO2\text{-}dw$	$ECO2\text{-}l$	$EBBCO2\text{-}tot$	$EBBnN2O_{icl}$	$EBBCH4_{icl}$	$EBBtot_{icl}$
$IDcl$	Name	%	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	%	%	%	%	%	%	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}	tCO$_2$e ha^{-1}
1																		
2																		
. . .																		
Icl																		

Finally, using the parameters specified in table 18 and the projected activity data for forest classes calculate the projected total non-CO$_2$ emissions from forest fires and report the results in table 19.

Table 19. Baseline non-CO$_2$ emissions from forest fires in the project area
(The selection of gases is subject to the latest VCS guidance on this matter, see table 4)

Project year t	Emissions of non-CO$_2$ gasses from baseline forest fires								Total baseline non-CO$_2$ emissions from forest fires in the project area	
	$ID_{icl} = 1$		$ID_{icl} = 2$		$ID_{icl} = \ldots$		$ID_{icl} = Icl$			
	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	annual $EBBBSLPA_t$	cumulative $EBBBSLPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
3										
...										
T										

Step 7: *Ex ante* estimation of actual carbon stock changes and non-CO$_2$ emissions in the project area

The goal of this step is to provide an *ex ante* estimate of future carbon stock changes and non-CO$_2$ emissions from forest fires under the project scenario ("actual"). Since actual carbon stock changes and GHG emissions will be subject to MRV-A, the rationale of estimating them at the beginning of a fixed baseline period is to assist in guiding optimal implementation of emission reduction measures, and to allow reasonable projections of revenue to be made.

7.1 *Ex ante* estimation of actual carbon stock changes

These are due to the following:

    7.1.1   Planned activities within the project area.

    7.1.2   Unplanned deforestation that cannot be avoided.

Carbon stock changes due to possible future catastrophic events cannot be predicted and are therefore excluded from the *ex ante* assessment.

7.1.1 *Ex ante* estimation of actual carbon stock changes due to planned activities

It is possible that certain discrete areas of forest within the project area will be subject to project activities that will change the carbon stocks of these areas compared to the baseline. Such activities are:

  a) Planned deforestation (e.g. to build project infrastructure);

b) Planned degradation (e.g. timber logging, fuel-wood collection or charcoal production);

c) Protection without harvesting leading to carbon sequestration in forest classes that at project start are below their carbon stock potential at maturity *in situ*.

If the project activity generates a significant decrease in carbon stocks during the fixed baseline period, the carbon stock change must be estimated *ex ante* and measured *ex post*. If the decrease is not significant, it must not be accounted, and *ex post* monitoring will not be required.

If the project activity generates an increase in carbon stocks, ignoring the carbon stock change is conservative. However, if the project proponent wishes to be credited for carbon stock increases on areas projected to be deforested in the baseline case, *ex post* monitoring of the carbon stock increase is mandatory[45].

Changes in carbon stocks that are not attributable to the project activity cannot be accounted.

Mandatory accounting of significant carbon stock decreases:

Where the AUD project activity includes planned deforestation, harvesting of timber[46], fuel-wood collection or charcoal production above the baseline case do the following:

a) Identify the forest areas (polygons) within the project area that will be subject to planned deforestation and planned degradation activities (logging, fuel-wood collection or charcoal production) during the project crediting period.

b) Prepare maps showing the annual locations of the planned activities.

c) Identify the forest classes that are located within these polygons.

d) Define activity data (annual areas) for each forest class, according to the planned interventions and types of intervention.

e) Estimate the impact of the planned activities on carbon stocks as follows:

- Planned deforestation: Conservatively assume that 100% of the carbon stocks will be lost.

- Areas subject to planned logging, fuel-wood collection or charcoal production above the baseline case: Conservatively assume that the carbon stock of these areas will be the lowest of the production cycle according to the planned levels of extraction.

f) Summarize the result of the previous assessments and calculations in Tables 20.a – 20.d. Tables 20.b and 20.c can only be filled out *ex post* and do not need to be filled out *ex ante* (i.e. their *ex ante* values are 0). These tables are for unpredictable carbon stock decreases that may have to be measured and reported *ex post* due to

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[45] If an area is not projected to be deforested, carbon stock increase in the project scenario cannot be accounted in this methodology, as the project category would be IFM and not AUD.

[46] Ignoring the carbon stocks in the long-lived wood products is conservative under the project scenario.

uncontrolled forest fires and other catastrophic events that may occur within the project area during project implementation.

Table 20.a. *Ex ante* **estimated actual carbon stock decrease due to planned deforestation in the project area**

Project year t	Areas of planned deforestation x Carbon stock change (decrease) in the project area								Total carbon stock decrease due to planned deforestation	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$\Box CPDdPA_t$	$\Box CPDdPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 20.b. *Ex ante* **estimated actual carbon stock decrease due to planned logging activities in the project area**

Project year t	Areas of planned logging activities x Carbon stock change (decrease) in the project area								Total carbon stock decrease due to planned logging activities	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APLPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Box Ctot_{icl,t}$	$\Box CPLdPA_t$	$\Box CPLdPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 20.c. *Ex ante* **estimated actual carbon stock decrease due to planned fuel wood collection and charcoal production in the project area**

Project year t	Areas of planned fuel-wood & charcoal activities x Carbon stock change (decrease) in the project areas								Total carbon stock decrease due to planned fuel-wood and charcoal activities	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$\Box CPFdPA_t$	$\Box CPFdPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
3										
. . .										
T										

Table 20.d. **Total** *ex ante* **carbon stock decrease due to planned activities in the project area**

Project year t	Total carbon stock decrease due to planned deforestation		Total carbon stock decrease due to planned logging activities		Total carbon stock decrease due to planned fuel-wood and charcoal activities		Total carbon stock decrease due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Box CPDdPA_t$	$\Box CPDdPA$	$\Box CPLdPA_t$	$\Box CPLdPA$	$\Box CPFdPA_t$	$\Box CPFdPA$	$\Box CPAdPA_t$	$\Box CPAdPA$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0								
1								
2								
. . .								
T								

Optional accounting of significant carbon stock increase

Consideration of carbon stock increase due to planned activities in areas that would be deforested in the baseline case is optional in this methodology and can always be omitted.

However, if the project area includes degraded and secondary forests that in the baseline case would be deforested and due to the project activity these areas will recover and sequester additional carbon, credits for the increased carbon stocks can be claimed. In the case, do the following:

a) Identify within the project area the polygons that are at the same time projected to be deforested in the baseline case and that are currently covered by secondary forests or degraded forests that have the potential to grow and accumulate significant carbon stocks;

b) Identify also the polygons representing areas of forests that will be subject to planned logging, fuel-wood collection and charcoal production activities under the project scenario and that have the potential to grow and accumulate significant carbon stocks after the periodical harvest cycle;

c) Prepare maps showing the annual locations of the polygons identified above;

d) Identify the forest classes existing in the polygons identified above;

e) Calculate activity data (annual areas) for each forest class in the polygons identified above;

f) For each forest class within the polygons, develop conservative growth projections using field data (measurements in plots of different ages), literature, existing databases and other credible and verifiable sources of information;

g) Calculate the projected increase in carbon stocks of each class. If the class is subject to periodical harvesting in the project case, assume that the maximum carbon stock is the long term average carbon stock (the average of a production cycle). Once a class reaches this level of carbon stock, do not allow any more carbon stock increase in the projections; and

h) Summarize the result of the previous assessments and calculations in Tables 21.a – 21.d. Tables 21.b and 21.c can only be filled out *ex post* and do not need to be filled out *ex ante* (i.e. their *ex ante* values are 0). These tables are for unpredictable carbon stock increases that may have to be measured and reported *ex post* due to forest regeneration on areas affected by forest fires and catastrophic events.

Table 21.a. *Ex ante* **estimated carbon stock increase due to planned protection without harvest in the project area**

Project year t	Area of forest classes growing without harvest in the project case x Carbon stock change (increase)								Total carbon stock increase due to growth without harvest	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPNiPA_t$	$\Delta CPNiPA$
	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0										
1										
2										
. . .										
T										

Table 21.b. *Ex ante* **estimated carbon stock increase following planned logging activities in the project area**

Project year t	Areas of planned logging activities x Carbon stock change (increase up to maximum long-term average)								Total carbon stock increase due to planned logging activities	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$\Delta CPLiPA_t$	$\Delta CPLiPA$
	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0										
1										
2										
. . .										
T										

Table 21.c. *Ex ante* estimated carbon stock increase following planned fuel-wood and charcoal activities in the project area

Project year t	Areas of planned fuel-wood and charcoal activities x Carbon stock change (increase up to maximum long-term average)								Total carbon stock increase due to planned fuel-wood and charcoal activities	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPFiPA_t$	$\Delta CPFiPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 21.d. Total *ex ante* estimated carbon stock increase due to planned activities in the project area

Project year t	Total carbon stock increase due to growth without harvest		Total carbon stock increase due to planned logging activities		Total carbon stock increase due to planned fuel-wood and charcoal activities		Total carbon stock increase due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPNiPA_t$	$\Delta CPNiPA$	$\Delta CPLiPA_t$	$\Delta CPLiPA$	$\Delta CPFiPA_t$	$\Delta CPFiPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0								
1								
2								
. . .								
T								

7.1.2 *Ex ante* estimation of carbon stock changes due to unavoidable unplanned deforestation within the project area

Some unplanned deforestation may happen in the project area despite the AUD project activity. The level at which deforestation will actually be reduced in the project case depends on the effectiveness of the proposed activities, which cannot be measured *ex ante*. *Ex post* measurements of the project results will be important to determine actual emission reductions.

To allow *ex ante* projections to be made, the project proponent shall make a conservative assumption about the effectiveness of the proposed project activities and estimate an Effectiveness Index (*EI*) between 0 (no effectiveness) and 1 (maximum effectiveness). The estimated value of *EI* is used to multiply the baseline projections by the factor (1 - *EI*) and the result shall be considered the *ex ante* estimated emissions from unplanned deforestation in the project case.

$$\Delta CUDdPA_t = \Delta CBSL_t * (1 - EI)| \qquad (20)$$

Where:

$\Delta CUDdPA_t$ Total *ex ante* actual carbon stock change due to unavoided unplanned deforestation at year *t* in the project area; tCO_2-e

$\Delta CBSL_t$ Total baseline carbon stock change at year *t* in the project area; tCO_2-e

EI   *Ex ante* estimated Effectiveness Index; %

t   1, 2, 3 … *T*, a year of the proposed project crediting period; dimensionless

7.1.3 *Ex ante* estimated net actual carbon stock changes in the project area

Summarize the result of the previous assessments in table 22.

Table 22. *Ex ante* estimated net carbon stock change in the project area under the project scenario

Project year *t*	Total carbon stock decrease due to planned activities		Total carbon stock increase due to planned activities		Total carbon stock decrease due to unavoided unplanned deforestation		Total carbon stock change in the project case	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Box CPAdPA_t$ tCO_2-e	$\Box CPAdPA$ tCO_2-e	$\Box CPAiPA_t$ tCO_2-e	$\Box CPAiPA$ tCO_2-e	$\Box CUDdPA_t$ tCO_2-e	$\Box CUDdPA$ tCO_2-e	$\Box CPSPA_t$ tCO_2-e	$\Box CPSPA$ tCO_2-e
0								
1								
2								
. . .								
T								

7.2 *Ex ante* estimation of actual non-CO_2 emissions from forest fires

Where forest fires have been included in the baseline scenario, non-CO_2 emissions from biomass burning must be included in the project scenario. This is done by multiplying the baseline emissions by the factor (1 − *EI*). The results are presented in table 23.

$$EBBPSPA_t = EBBBSPA_t * (1 - EI) \qquad (21)$$

Where:

EBBPSPA$_t$	Total *ex ante* actual non-CO_2 emissions from forest fire due to unavoided unplanned deforestation at year t in the project area; tCO_2-e
EBBBSPA$_t$	Total non-CO_2 emissions from forest fire at year t in the project area; tCO_2-e
EI	*Ex ante* estimated Effectiveness Index; %
t	1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

Table 23. Total *ex ante* estimated actual emissions of non-CO_2 gasses due to forest fires in the project area

Project year t	Total *ex ante* estimated actual non-CO_2 emissions from forest fires in the Project area	
	EBBPSPA$_t$ annual tCO_2-e	***EBBPSPA*** cumulative tCO_2-e
0		
1		
2		
. . .		
T		

7.3 Total *ex ante* estimations for the project area

Table 24. Total *ex ante* estimated actual net carbon stock changes and emissions of non-CO$_2$ gasses in the project area

Project year t	Total *ex ante* carbon stock decrease due to planned activities		Total *ex ante* carbon stock increase due to planned activities		Total *ex ante* carbon stock decrease due to unavoided unplanned deforestation		Total *ex ante* net carbon stock change		Total *ex ante* estimated actual non-CO$_2$ emissions from forest fires in the project area	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\square CPAdPA_t$	$\square CPAdPA$	$\square CPAiPA_t$	$\square CPAiPA$	$\square CUDdPA_t$	$\square CUDdPA$	$\square CPSPA_t$	$\square CPSPA$	$EBBPSPA_t$	$EBBPSPA$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Step 8: *Ex ante* estimation of leakage

The goal of this step is to provide an *ex ante* estimate of the possible decrease in carbon stock and increase in GHG emissions (other than carbon stock change) due to leakage. The rationale for estimating leakage *ex ante* is to assist in guiding the design of optimal leakage prevention measures, identify sources of leakage that are potentially significant, and therefore subject to MRV, and to allow making reasonable projections of carbon and other project revenues.

Two sources of leakage are considered in this methodology and must be addressed:

    8.1   Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention measures;

    8.2   Decrease in carbon stocks and increase in GHG emissions associated with activity displacement leakage.

8.1 *Ex ante* estimation of the decrease in carbon stocks and increase in GHG emissions due to leakage prevention measures

To reduce the risk of activity displacement leakage, baseline deforestation agents should be given the opportunity to participate in activities within the project area and in specially designated leakage management areas (outside the project area) that together will replace baseline income, product generation and livelihood of the agents as much as possible, so that deforestation will be reduced and the risk of displacement minimized.

If leakage prevention measures include tree planting, agricultural intensification, fertilization,

fodder production and/or other measures to enhance cropland and grazing land areas, a reduction in carbon stocks and/or an increase in GHG emissions may occur compared to the baseline case. If such decrease in carbon stock or increase in GHG emission is significant, it must be accounted and monitoring will be required. If it is not significant, it must not be accounted and *ex post* monitoring will not be necessary.

If leakage prevention activities are associated to other VCS or UNFCCC registered (and VCS endorsed) project activities, changes in carbon stocks and GHG emissions that are already subject to MRV in such other registered project activities must not be estimated and accounted to avoid double-counting.

The following activities in leakage management areas could occasion a decrease in carbon stocks or an increase in GHG emissions:

8.1.1 Carbon stock changes due to activities implemented in leakage management areas;

8.1.2 Methane (CH_4) and nitrous oxide (N_2O) emissions from livestock intensification (involving a change in the animal diet and/or animal numbers).

Note that nitrous oxide (N_2O) emissions from nitrogen fertilization are considered always insignificant according to the most recent version of the VCS Standard.

Consumption of fossil fuels is considered always insignificant in AUD project activities and must not be considered.

8.1.1 Carbon stock changes due to activities implemented in leakage management areas

Leakage prevention activities generating a decrease in carbon stocks should be avoided, but if such activities are necessary the decrease in carbon stock associated to the leakage prevention activity must be estimated *ex ante* and accounted, if significant.

To estimate carbon stock changes in leakage management areas do the following:

a) Prepare a list of the planned leakage prevention activities and briefly describe each of them in the PD;

b) Prepare a map of the planned leakage prevention activities showing annual areas of intervention and type of intervention;

c) Identify the areas where leakage prevention activities will impact on carbon stocks;

d) Identify the non-forest classes[47] existing within these areas in the baseline case;

e) Measure the carbon stocks in the identified classes or use conservative literature estimates for each of the identified classes. If some classes have changing carbon stocks in the baseline, do carbon stock projections using growths data and other relevant and verifiable sources of information;

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[47] Forest classes cannot be present in leakage management areas at the project start date (see section 1.1.4).

f) Report in table 25.a the projected baseline carbon stock changes in the leakage management areas;

g) According to the planned interventions, estimate the projected carbon stocks in the leakage management areas under the project scenario. Use conservative growth projections. Report the result in table 25.b; and

h) Calculate the net carbon stock changes that the planned leakage prevention measures are expected to occasion during the fixed baseline period and, optionally, the project crediting period. Report the results of the calculations in table 25.c

- If the net sum of carbon stock changes within a monitoring period is more than zero, leakage prevention measures are not causing any carbon stock decrease. The net increase shall conservatively be ignored in the calculation of net GHG emission reductions of the project activity.

- If the net sum is negative, determine the significance using the most recent version of the EB-CDM approved "Tool for testing significance of GHG emissions in A/R CDM project activities". If the decrease is significant, it must be accounted in the *ex ante* estimation of leakage and carbon stock changes in the land units where leakage prevention measures are implemented will be subject to MRV. If the decrease is not significant, it must not be accounted and carbon stock changes will not be subject to MRV.

Table 25.a. *Ex ante* estimated carbon stock change in leakage management areas in the baseline case

Project year t	Carbon stock changes in leakage management areas in the baseline case								Total carbon stock change in the baseline case	
	$ID_{icl} = 1$		$ID_{icl} = 2$		$ID_{icl} = \ldots$		$ID_{icl} = Icl$		annual	cumulative
	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$\Box CBSLLKt$	$\Box CBSLLK$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 25.b. *Ex ante* **estimated carbon stock change in leakage management areas in the project case**

Project year t	Carbon stock changes in leakage management areas in the project case								Total carbon stock change in the project case	
	$ID_{fcl} = 1$		$ID_{fcl} = 2$		$ID_{fcl} = \ldots$		$ID_{fcl} = Fcl$		annual	cumulative
	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$\Box CPSLKt$	$\Box CPSLK$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 25.c. *Ex ante* **estimated net carbon stock change in leakage management areas**

Project year t	Total carbon stock change in the baseline case		Total carbon stock change in the project case		Net carbon stock change due to leakage prevention measures	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Box CBSLLKt$	$\Box CBSLLK$	$DCPSLKt$	$DCPSLK$	$\Box CLPMLKt$	$\Box CLPMLK$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0						
1						
2						
. . .						
T						

8.1.2 *Ex ante* estimation of CH$_4$ and N$_2$O emissions from grazing animals

To estimate the increase in emissions of methane (CH$_4$) and nitrous oxide (N$_2$O) from grazing animals in leakage management areas do the following:

a) Specify the annual areas that will have grazing activities in the leakage management areas;

b) Briefly describe the types of animal, forage and manure management. Use table 26 to report the key parameters required to perform the calculation of GHG emissions;

c) Determine the number of animals in the baseline case and under the project scenario based on available areas and forage. The difference must be considered for the calculation of the increase in GHG emissions; and

d) Methods to estimate emissions from enteric fermentation and manure management are given in appendix 4. Perform the final calculations using equation 22 and report the results in table 27.

The GHG emissions are estimated as follows:

$$EgLK_t = ECH4ferm_t + ECH4man_t + EN2Oman_t \tag{22}$$

Where:

$EgLK_t$ Emissions from grazing animals in leakage management areas at year t; tCO$_2$-e yr^{-1}

$ECH4ferm_t$ CH$_4$ emissions from enteric fermentation in leakage management areas at year t; tCO$_2$-e yr^{-1}

$ECH4man_t$ CH$_4$ emissions from manure management in leakage management areas year t; tCO$_2$-e yr^{-1}

$EN2Oman_t$ N$_2$O emissions from manure management in leakage management areas at year t; tCO$_2$-e yr^{-1}

t 1, 2, 3, … T years of the project crediting period; dimensionless

Table 26. Parameters used for the *ex ante* estimation of GHG emissions from grazing activities

Parameter	Value used for calculations	Unit	Description
EF1		kg CH$_4$ head^{-1} yr^{-1}	Enteric CH$_4$ emission factor for the livestock group
EF2		kg CH4 head^{-1} yr^{-1}	Manure management CH$_4$ emission factor for the livestock group
EF3		kg N$_2$O-N (kg N^{-1}) head^{-1} yr^{-1}	Emission factor for N$_2$O emissions from manure management for the livestock group
EF4		kg N$_2$O-N (kg NH$_3$-N and NO$_x$-N emitted)$^{-1}$ head^{-1} yr^{-1}	Emission factor for N$_2$O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces
DBI		kg d.m. head^{-1} day^{-1}	Daily biomass intake
Nex		kg N head^{-1} yr^{-1}	Annual average N excretion per livestock head
Fracgas		kg NH$_3$-N and NO$_x$-N emitted (Kg N)$^{-1}$	Fraction of managed livestock manure nitrogen that volatilizes as NH$_3$ and NO$_x$ in the manure management phase

Table 27. *Ex ante* **estimation of leakage emissions above the baseline from grazing animals in leakage management areas**

Project year t	$Aforage_t$ ha	$Pforage_t$ kg d. m. yr^{-1}	$Population_t$ Nr heads	$ECH4ferm_t$ tCO$_2$-e	$ECH4man_t$ tCO$_2$-e	$EdirN20man_t$ tCO$_2$-e	$EidN20man_t$ tCO$_2$-e	$EN2Oman_t$ tCO$_2$-e	annual $EgLK_t$ tCO$_2$-e	cumulative $EgLK_t$ tCO$_2$-e
0										
1										
2										
…										
T										

8.1.3 Total *ex ante* estimated carbon stock changes and increases in GHG emissions due to leakage prevention measures

Summarize the results of the previous estimations in table 28, where only significant sources must be reported.

Table 28. *Ex ante* **estimated total emissions above the baseline from leakage prevention activities**

Project year t	Cabon stock decrease due to leakage prevention measures		Total *ex ante* GHG emissions from increased grazing activities		Total *ex ante* increase in GHG emissions due to leakage prevention measures	
	annual	cumulative	annual	cumulative	annual	cumulative
	$CLPMLKt$	$CLPMLK$	$EgLK_t$	$EgLK_t$	$ELPMLK_t$	$ELPMLK$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0						
1						
2						
…						
T						

8.2 *Ex ante* estimation of the decrease in carbon stocks and increase in GHG emissions due to activity displacement leakage

Activities that will cause deforestation within the project area in the baseline case could be displaced outside the project boundary due to the implementation of the AUD project activity. If carbon stocks in the leakage belt area will decrease more during project implementation than projected in the baseline case, this will be an indication that leakage due to displacement of baseline activities has occurred. Leakage due to activity displacement can thus be estimated by *ex post* monitoring of deforestation in the leakage belt and comparing *ex post* observed deforestation with *ex ante* projected baseline deforestation. A baseline for the leakage belt is therefore necessary and methods to establish this baseline are similar to those explained in section 6.1.2.

Do the *ex ante* baseline assessment of the leakage belt and report the result in the following tables:

Using Method 1 (see section 6.1.2)

Table 29.a. **Baseline carbon stock change in pre-deforestation (forest) classes**

Project year t	Carbon stock changes in initial (pre-deforestation) forest classes in the leakage belt								Total carbon stock change in initial forest classes	
	$ID_{icl} = 1$		$ID_{icl} = 2$		$ID_{icl} = \ldots$		$ID_{icl} = I_{cl}$		annual	cumulative
	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$\Delta CBSLLKi_t$	$\Delta CBSLLKi$
	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0										
1										
. . .										
T										

Table 29.b. **Baseline carbon stock change in post-deforestation (non-forest) classes**

Project year t	Carbon stock changes in final (post-deforestation) non-forest classes on the leakage belt								Total carbon stock change in final non-forest classes	
	$ID_{fcl} = 1$		$ID_{fcl} = 2$		$ID_{fcl} = \ldots$		$ID_{fcl} = F_{cl}$		annual	cumulative
	$ABSLLK_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLLK_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLLK_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLLK_{fcl,t}$	$Ctot_{fcl,t}$	$\Delta CBSLLKf_t$	$\Delta CBSLLKf$
	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0										
1										
. . .										
T										

Table 29.c. Total net baseline carbon stock change in the leakage belt
(Calculated with Method 1: Activity data per class)

Project year t	Total carbon stock change in initial forest classes		Total carbon stock change in final non-forest classes		Total baseline carbon stock change	
	annual	cumulative	annual	cumulative	annual	cumulative
	$CBSLLKi_t$	$CBSLLKi$	$CBSLLKf_t$	$CBSLLKf$	$CBSLLK_t$	$CBSLLK$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0						
1						
. . .						
T						

Or, using Method 2 (see section 6.1.2):

Table 30. Carbon stock change factors per category of LU/LC change

Category from Table 7b		Average *carbon stock* ± 90% CI of the "initial" *class*														Average *carbon stock* ± 90% CI of the "final" *class*														Average *carbon stock change facto r* ± 90% CI														
		Cab		*Cbb*		*Cdw*		*Cl*		*Csoc*		*Cwp*		*Ctot*		*Cab*		*Cbb*		*Cdw*		*Cl*		*Csoc*		*Cwp*		*Ctot*		□*Cab*		□*Cbb*		□*Cdw*		□*Cl*		□*csoc*		□*Cwp*		□*Ctot*	
IDct	*Name*	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹	average stock change tCO₂e ha⁻¹	± 90% CI tCO₂e ha⁻¹
I1/F1																																												
I1/F2																																												
I1/F3																																												
I1/F4																																												
I2/F1																																												
I2/F2																																												
I2/F3																																												
I2/F4																																												
I3/F1																																												
I3/F2																																												

Table 31. **Total net baseline carbon stock change in the leakage belt**
(Calculated with Method 2: Activity data per category)

Project year t	Activity data per category x Carbon stock change factor in the leakage belt								Total baseline carbon stock change	
	$ID_{ct} = 1$		$ID_{ct} = 2$		$ID_{ct} = \ldots$		$ID_{ct} = Ict$		annual	cumulative
	$ABSLLK_{ct,t}$	$\Delta Ctot_{ct,t}$	$ABSLLKct,t$	$\Delta Ctot_{ct,t}$	$ABSLLKct,t$	$\Delta Ctot_{ct,t}$	$ABSLLKct,t$	$\Delta Ctot_{ct,t}$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
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2										
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T										

However, *ex ante*, activity displacement leakage can only be guessed based on the anticipated combined effectiveness of the proposed leakage prevention measures and project activities.

This shall be done by multiplying the estimated baseline carbon stock changes for the project area by a "Displacement Leakage Factor" (*DLF*) representing the percent of deforestation expected to be displaced outside the project boundary[48].

If emissions from forest fires have been included in the baseline, the *ex ante* emissions from forest fires due to activity displacement leakage will be calculated by multiplying baseline forest fire emissions in the project area by the same *DLF* used to estimate the decrease in carbon stocks.

Report the *ex ante* estimated leakage due to activity displacement in table 32.

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[48] If deforestation agents do not participate in leakage prevention activities and project activities, the Displacement Factor shall be 100%. Where leakage prevention activities are implemented the factor shall be equal to the proportion of the baseline agents estimated to be given the opportunity to participate in leakage prevention activities and project activities.

Table 32. *Ex ante* estimated leakage due to activity displacement

Project year t	Total *ex ante estimated* decrease in carbon stocks due to displaced deforestation		Total *ex ante estimated* increase in GHG emissions due to displaced forest fires	
	annual $\Box CADLK_t$ tCO$_2$-e	cumulative $\Box CADLK$ tCO$_2$-e	annual $EADLK_t$ tCO$_2$-e	cumulative $EADLK$ tCO$_2$-e
0				
1				
2				
. . .				
T				

8.3 *Ex ante* estimation of total leakage

Summarize the result all sources of leakage in table 33.

Table 33. *Ex ante* estimated total leakage

Project year t	Total *ex ante* GHG emissions from increased grazing activities		Total *ex ante* increase in GHG emissions due to displaced forest fires		Total *ex ante* decrease in carbon stocks due to displaced deforestation		Carbon stock decrease due to leakage prevention measures		Total net carbon stock change due to leakage		Total net increase in emissions due to leakage	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$EgLK_t$	$EgLK$	$EADLK_t$	$EADLK$	$\Delta CADLK_t$	$\Delta CADLK$	$\Delta CLPMLK_t$	$\Delta CLPMLK$	ΔCLK_t	ΔCLK	ELK_t	ELK
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0												
1												
2												
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Step 9: *Ex ante* total net anthropogenic GHG emission reductions

9.1 Significance assessment

All carbon pools and sources of GHG emissions considered in this methodology must be calculated to assess their significance. Use the latest EB-CDM approved "Tool for testing significance of GHG emissions in A/R CDM project activities" to determine the significance of each of the *ex ante* calculated carbon stock changes and GHG emissions. Report the result of the analysis in the PD.

Only significant sources and pools need to be accounted in the calculation of net anthropogenic GHG emission reductions (step 9.2) and only significant sources and pools must be considered in the monitoring plan.

9.2 Calculation of e*x-ante* estimation of total net GHG emissions reductions

The net anthropogenic GHG emission reduction of the proposed AUD project activity is calculated as follows:

$$\Delta REDD_t = (\Delta CBSLPA_t + EBBBSLPA_t) - (\Delta CPSPA_t + EBBPSPA_t) - (\Delta CLK_t + ELK_t) \qquad (23)$$

Where:

$\Delta REDD_t$ *Ex ante* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*; tCO$_2$e

$\Delta CBSLPA_t$ Sum of baseline carbon stock changes in the project area at year *t*; tCO$_2$e

         Note: The absolute values of $\Delta CBSLPA_t$ shall be used in equation 23.

$EBBBSLPA_t$ Sum of baseline emissions from biomass burning in the project area at year *t*; tCO$_2$e

$\Delta CPSPA_t$ Sum of *ex ante* estimated actual carbon stock changes in the project area at year *t*; tCO$_2$e

         Note: If $\Delta CPSPA_t$ represents a net increase in carbon stocks, a negative sign before the absolute value of $\Delta CPSPA_t$ shall be used. If $\Delta CPSPA_t$ represents a net decrease, the positive sign shall be used.

$EBBPSPA_t$ Sum of (*ex ante* estimated) actual emissions from biomass burning in the project area at year *t*; tCO$_2$e

ΔCLK_t Sum of *ex ante* estimated leakage net carbon stock changes at year *t*; tCO$_2$e

         Note: If the cumulative sum of ΔCLK_t within a fixed baseline period is *> 0*, ΔCLK_t shall be set to zero.

ELK_t Sum of *ex ante* estimated leakage emissions at year *t*; tCO$_2$e

t   1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

9.3 Calculation of e*x-ante* Verified Carbon Units (VCUs)

The number of Verified Carbon Units (VCUs) to be generated through the proposed AUD project activity at year *t* is calculated as follows:

$$VCU_t = \Delta REDD_t - VBC_t \tag{24}$$

$$VBC_t = (\Delta CBSLPA_t - \Delta CPSPA_t) * RF_t \tag{25}$$

Where:

VCU_t Number of Verified Carbon Units that can be traded at time *t*; t CO_2-e

             <u>Note:</u> If $VCU_t < 0$ no credits (VCUs) will be awarded to the proponents of the AUD project activity. VCUs can only be granted if the following condition is met:

$$\sum_{t=0}^{t} \Delta REDD_t > 0 \tag{26}$$

$\Delta REDD_t$ *Ex ante* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*; tCO_2-e ha^{-1}

VBC_t Number of Buffer Credits deposited in the VCS Buffer at time *t*; t CO_2-e

$\Delta CBSLPA_t$ Sum of baseline carbon stock changes in the project area at year *t*; tCO_2e

$\Delta CPSPA_t$ Sum of *ex ante* estimated actual carbon stock changes in the project area at year *t*; tCO_2-e ha^{-1}

RF_t Risk factor used to calculate VCS buffer credits; %

             <u>Note:</u> RF_t is a risk factor to be determined using the latest version of the VCS-approved AFOLU Non-Permanence Risk Tool.

t   1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

See also the latest version of the Registration and Issuance Process document for information on this subject matter[49].

Present the result of the calculations in table 34.

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[49] Available at: http://www.v-c-s.org

Table 34. *Ex ante* **estimated net anthropogenic GHG emission reductions ($\Delta REDD_t$) and Voluntary Carbon Units (VCU_t)**

Project year t	Baseline carbon stock changes		Baseline GHG emissions		*Ex ante* project carbon stock changes		*Ex ante* project GHG emissions		*Ex ante* leakage carbon stock changes		*Ex ante* leakage GHG emissions		*Ex ante* net anthropogenic GHG emission reductions		*Ex ante* VCUs tradable		*Ex ante* buffer credits	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLPA_t$	$\Delta CBSLPA$	$EBBBSLPA_t$	$EBBBSLPA$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EBBPSPA_t$	$EBBPSPA$	ΔCLK_t	ΔCLK	ELK_t	ELK	$\Delta REDD_t$	$\Delta REDD$	VCU_t	VCU	VBC_t	VBC
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0																		
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PART 3 – Methodology for monitoring and re-validation of the baseline

The *ex post* methodology (to be implemented immediately after project start) includes two main tasks:

1) Monitoring of carbon stock changes and GHG emissions for periodical verifications within the fixed baseline period; and

2) Monitoring of key baseline parameters for revisiting the baseline at the end of the fixed baseline period.

Task 1: Monitoring of carbon stock changes and GHG emissions for periodical verifications

There are three main monitoring tasks:

1.1 Monitoring of actual carbon stock changes and GHG emissions within the project area;

1.2 Monitoring of leakage; and

1.3 *Ex post* calculation of net anthropogenic GHG emission reduction.

Prepare a <u>Monitoring Plan</u> describing how these tasks will be implemented. For each task the monitoring plan must include the following sections:

a) Technical description of the monitoring tasks.

b) Data to be collected (see appendix 5).

c) Overview of data collection procedures.

d) Quality control and quality assurance procedures.

e) Data archiving.

f) Organization and responsibilities of the parties involved in all the above.

To allow a transparent comparison between *ex ante* and *ex post* estimates, use the same formats and tables presented in Part 2 of the methodology to report the results of monitoring.

1.1 Monitoring of actual carbon stock changes and GHG emissions within the project area

This task involves:

1.1.1 Monitoring of project implementation;

1.1.2 Monitoring of land-use and land-cover change;

1.1.3 Monitoring of carbon stocks and non-CO_2 emissions; and

1.1.4 Monitoring of impacts of natural disturbances and other catastrophic events.

1.1.1 Monitoring of project implementation

Project activities implemented within the project area should be consistent with the management plans of the project area and the PD. All maps and records generated during project implementation should be conserved and made available to VCS verifiers at verification for inspection to demonstrate that the AUD project activity has actually been implemented.

1.1.2 Monitoring of land-use and land-cover change within the project area

The categories of changes that may be subject to MRV are summarized in table 35.

Table 35. Categories subject to MRV

ID	Type	Conditions under which monitoring is mandatory	Explanations
I	Area of forest land converted to non-forest land.	Mandatory in all AUD project activities	
II	Area of forest land undergoing carbon stock decrease.	Mandatory only for AUD project activities having planned logging, fuel-wood collection and charcoal production activities above the baseline.	Change in carbon stock must be significant according to *ex ante* assessment, otherwise monitoring is not required.
III	Area of forest land undergoing carbon stock increase.	Mandatory only for AUD project activities wishing to claim carbon credits for carbon stock increase.	Increase must be significant according to *ex ante* assessment and can only be accounted on areas that will be deforested in the baseline case.

If the project area is located within a region subject to MRV by a jurisdictional program, the MRV data generated by this program must be used.

Similarly, if the project area is located within a region that is subject to a monitoring program that is approved or sanctioned by the national or sub-national government, the data generated by such program must be used, unless they are not applicable according to the criteria listed below:

a) Monitoring occurs in the entire project area and, if the project must monitor a leakage belt, in the leakage belt.

b) If data from the existing monitoring program are used to periodically revisit the baseline, monitoring must occur in the entire reference region at least at the beginning, middle and end of the fixed baseline period.

c) At least category I (table 35) is subject to monitoring (conversion of forest land to non-forest land).

d) It the project must do a monitoring of other categories (II and/or III) and these are not included in the existing program, the existing program can only be used for monitoring category I, and the project proponent must implement a separate monitoring program for category II and/or III.

e) Monitoring will occur during the entire fixed baseline period.

f) Monitoring methods are transparently documented and are similar to those used to determine the baseline of the AUD project activity.

g) Monitoring protocols and data must be accessible for inspection by VCS accredited verifier.

If no existing monitoring program exist or can be used, monitoring must be done by the project proponent or outsourced to a third party having sufficient capacities to perform the monitoring tasks. Methods used to monitor LU/LC change categories and to assess accuracy must be similar to those explained in part 2, step 2.4 and part 2, step 2.5, respectively.

1.1.3 Monitoring of carbon stock changes and non-CO$_2$ emissions from forest fires

Monitoring of carbon stock changes

In most cases, the *ex ante* estimated average carbon stocks per LU/LC class (or carbon stock change factors per LU/LC change category) will not change during a fixed baseline period and monitoring of carbon stocks will not be necessary.

However, monitoring of carbon stocks is mandatory in the following cases:

Within the project area:

a) Areas subject to significant carbon stock decrease in the project scenario according to the *ex ante* assessment. These will be areas subject to controlled deforestation and planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, carbon stock changes must be estimated at least once after each harvest event.

b) Areas subject to unplanned and significant carbon stock decrease, e.g. due to uncontrolled forest fires and other catastrophic events. In these areas, carbon stock losses must be estimated as soon as possible after the catastrophic event. See section 1.1.4 below for more detailed guidance.

Within leakage management areas:

a) Areas subject to planned and significant carbon stock decrease in the project scenario according to the *ex ante* assessment. In these areas, carbon stocks must be estimated at least once after the planned event that caused the carbon stock decrease.

Monitoring of carbon stocks is optional in the following cases:

Within the project area:

a) Areas subject to carbon stock increase after planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, the carbon stock increase occurring after the harvest event can be measured and accounted, when significant.

b) Areas recovering after disturbances, such unplanned forest fires and other catastrophic events. In these areas, the carbon stock increase occurring after the catastrophic event can be measured and accounted, when significant. See section 1.1.4 below for more detailed guidance.

Within leakage management areas:

a) Areas subject to carbon stock increase due to leakage prevention measures. In these areas, the carbon stock increase can be measured and accounted only up to the amount necessary to offset any carbon stock decrease caused by leakage prevention measures in other leakage management areas or in previous years.

Within the leakage belt:

a) Areas undergoing significant changes in carbon stock may be measured at the end of each fixed baseline period in order to update carbon stock information for the subsequent period.

Where carbon stocks are monitored, the methods on sampling and measuring carbon stocks described in appendix 3 must be used.

Some project proponents may wish to do additional carbon stock measurements during project implementation to gain accuracy and credits. If new and more accurate carbon stock data become available, these can be used to estimate the net anthropogenic GHG emission reduction of the subsequent fixed baseline period. For the current fixed baseline period, new data on carbon stocks can only be used if they are validated by an accredited VCS verifier. If new data are used in the current fixed baseline period, the baseline must be recalculated using the new data.

The results of monitoring activity data and carbon stocks must be reported using the same formats and tables used for the *ex ante* assessment:

Table 20.a   *Ex post* carbon stock decrease due to planned and unplanned deforestation in the project area.

Table 20.b   *Ex post* carbon stock decrease due to planned logging activities.

Table 20.c   *Ex post* carbon stock decrease due to planned fuel-wood and charcoal activities.

Table 20.d   Total *ex post* carbon stock decrease due to planned activities in the project area.

Table 20.e   *Ex post* actual carbon stock decrease due to forest fires in the project area

Project year t	Areas affected by forest fires x Carbon stock change (decrease)								Total carbon stock decrease due to forest fires	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$AUFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Box Ctot_{icl,t}$	$\Box CUFdPA_t$	$\Box CUdFPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
...										
T										

Table 20.f *Ex post* carbon stock decrease due to catastrophic events in the project area

Project year t	Areas affected by catastrophic events x Carbon stock change (decrease)								Total carbon stock decrease due to catastrophic events	
	$ID_{cl}=1$		$ID_{cl}=2$		$ID_{cl}=\ldots$		$ID_{cl}=Icl$		annual	cumulative
	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUCdPA_t$	$\Delta CUCdPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 20.g Total *ex post* carbon stock decrease due to forest fires and catastrophic events

Project year t	Total carbon stock decrease due to forest fires		Total carbon stock decrease due to catastrophic events		Total carbon stock decrease due to forest fires and catastrophic events	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CUFdPA_t$	$\Delta CUFdPA$	$\Delta CUCdPA_t$	$\Delta CUCdPA$	$\Delta CFCdPA_t$	$\Delta CFCdPA$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0						
1						
2						
. . .						
T						

Table 21.e *Ex post* actual carbon stock increase on areas affected by forest fires in the project area

Project year t	Areas affected by forest fires x Carbon stock change (increase)								Total carbon stock increase due to forest fires	
	$ID_{cl}=1$		$ID_{cl}=2$		$ID_{cl}=\ldots$		$ID_{cl}=Icl$		annual	cumulative
	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUFiPA_t$	$\Delta CUFiPA$
	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	ha	tCO$_2$-e ha^{-1}	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Table 21.f *Ex post* **carbon stock increase on areas affected by catastrophic events**

Project year t	Areas affected by catastrophic events x Carbon stock change (increase) in the project area								Total carbon stock increase due to catastrophic events	
	$ID_{cl} = 1$		$ID_{cl} = 2$		$ID_{cl} = \ldots$		$ID_{cl} = Icl$		annual	cumulative
	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUCiPA_t$	$\Delta CUCiPA$
	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	ha	$tCO_2\text{-e ha}^{-1}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0										
1										
2										
. . .										
T										

Table 21.g **Total** *ex post* **carbon stock increase on areas affected by forest fires and catastrophic events**

Project year t	Total carbon stock increase due to forest fires		Total carbon stock increase due to catastrophic events		Total carbon stock increase due to forest fires and catastrophic events	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CUFiPA_t$	$\Delta CUFiPA$	$\Delta CUCiPA_t$	$\Delta CUCiPA$	$\Delta CFCiPA_t$	$\Delta CFCiPA$
	$tCO_2\text{-e}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$	$tCO_2\text{-e}$
0						
1						
2						
. . .						
T						

Table 22. *Ex post* **estimated net carbon stock change in the project area under the project scenario**

Project year t	Total carbon stock decrease due to planned activities		Total carbon stock increase due to planned activities		Total carbon stock decrease due to fires and catastrophic events		Total carbon stock increase due to fires and catastrophic events		Total *ex post* carbon stock change in the project case	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$	$\Delta CFCdPA_t$	$\Delta CFCdPA$	$\Delta CFCiPA_t$	$\Delta CFCiPA$	$\Delta CPSPA_t$	$\Delta CPSPA$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0										
1										
2										
. . .										
T										

Monitoring of non-CO$_2$ emissions from forest fires

These are subject to monitoring and accounting, when significant. In this case, under the project scenario it will be necessary to monitor the variables of table 18 within the project area and to report the results in table 19.

1.1.4 Monitoring of impacts of natural disturbances and other catastrophic events

Decreases in carbon stocks and increases in GHG emissions (e.g. in case of forest fires) due to natural disturbances (such as hurricanes, earthquakes, volcanic eruptions, tsunamis, flooding, drought[50], fires, tornados or winter storms) or man-made events, including those over which the project proponent has no control (such as acts of terrorism or war), are subject to monitoring and must be accounted under the project scenario, when significant. Use tables 20.e, 20.f and 20.g to report carbon stock decreases and, optionally, tables 21.e, 21.f and 21.g to report carbon stock increases that may happen on the disturbed lands after the occurrence of an event. Use tables 18 and 19 to report emissions from forest fires.

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[50] When the 1997-1998 El Niño episode provoked severe droughts in the Amazon and Indonesia, large areas of tropical forest burned, releasing 0.2 to 0.,4 Gt of carbon to the atmosphere (de Mendonça *et al.*, 2004; Siegert *et al.*, 2001; Page *et al.*, 2002). If droughts become more severe in the future through more frequent and severe el Niño episodes (Trenberth and Hoar, 1997; Timmermann *et al.*, 1999), or the dry season becomes lengthier due to deforestation-induced rainfall inhibition (Nobre *et al.*, 1991; Silva-Dias *et al.*, 2002) or there are rainfall reductions due to climate change (White *et al.*, 1999; Cox *et al.*, 2000), then substantial portions of the 200 Gt of carbon stored globally on tropical forest trees could be transferred to the atmosphere in the coming decades (Santilli *et al.*, 2005).

If the area (or a sub-set of it) affected by natural disturbances or man-made events generated VCUs in past verifications, the total net change in carbon stocks and GHG emissions in the area(s) that generated VCUs must be estimated, and an equivalent amount of VCUs must be cancelled from the VCS buffer.

No VCUs can be issued to the project until all carbon stock losses and increases in GHG emissions have been offset, i.e. until the following condition is satisfied:
$$\sum_{t=0}^{t} REDD_t > 0 \tag{27}$$

Where:

$\Delta REDD_t$ *Ex post* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*; tCO$_2$e

t   1, 2, 3 … *T*, a year of the proposed project crediting period; dimensionless

1.1.5 Total *ex post* estimated actual net carbon stock changes and GHG emissions in the project area

Summarize the results of all *ex post* estimations in the project area using the same table format used for the *ex ante* assessment:

Table 24:   Total *ex post* estimated actual net changes in carbon stocks and emissions of GHG gases in the project area.

1.2 Monitoring of leakage

Monitoring of leakage may not be required if the project area is located within a jurisdiction that is monitoring, reporting, verifying and accounting GHG emissions from deforestation under a VCS or UNFCCC registered (and VCS endorsed) program. In such cases, the most recent VCS guidelines on this subject matter shall be applied.

In all other circumstances, the sources of leakage identified as significant in the *ex ante* assessment are subject to monitoring. Two sources of leakage are potentially subject to monitoring:

     1.2.1   Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention activities;

     1.2.2   Decrease in carbon stocks and increase in GHG emissions in due to activity displacement leakage.

1.2.1 Monitoring of carbon stock changes and GHG emissions associated to leakage prevention activities

Monitoring of the sources of emissions associated with leakage prevention activities must follow the methods and tools described in part 2, step 8.1 of the methodology.

Results must be reported using the same formats and tables used in the *ex ante* assessment:

Table 25.b   *Ex post* carbon stock change in leakage management areas.

Table 25.c   *Ex post* net carbon stock change in leakage management areas[51].

Table 26   *Ex post* parameters for estimating GHG emissions from grazing activities

Table 27   *Ex post* estimation of emissions from grazing animals in leakage management areas.

Table 28   *Ex post* estimation of net carbon stock changes and GHG emissions from leakage prevention activities.

1.2.2 Monitoring of carbon stock decrease and increases in GHG emissions due to activity displacement leakage

Monitoring of carbon stock changes

Deforestation above the baseline in the leakage belt area will be considered activity displacement leakage.

Activity data for the leakage belt area must be determined using the same methods applied to monitoring deforestation activity data (category I, table 35) in the project area. Monitoring of the categories II and III outside the project area is not required because no credits are claimed for avoided degradation under this methodology.

The result of the *ex post* estimations of carbon stock changes must be reported using the same table formats used in the *ex ante* assessment of baseline carbon stock changes in the leakage belt.

Table 29.a   *Ex post* carbon stock change in pre-deforestation forest classes in the leakage belt.

Table 29.b   *Ex post* carbon stock change in post-deforestation non-forest classes in the leakage belt.

Table 29.c   *Ex post* total net carbon stock changes in the leakage belt (when using method 1 based on activity data per class).

or

Table 31   *Ex post* total net carbon stock changes in the leakage belt (when using method 2 based on activity data per category).

Leakage will be calculated as the difference between the *ex ante* and the *ex post* assessment. Report the results in table 29.c

Table 29.c.   Total net baseline carbon stock change in the leakage belt

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[51]   Calculations of total net carbon stock changes in Leakage Management Areas use the ex ante estimated baseline carbon stock changes in the Leakage Management Area and the measured ex post carbon stock changes. If the cumulative value of the carbon stock change within a Fixed Baseline Period is > 0, $\Delta CLPMLK_t$ shall be set to zero.

(Calculated with Method 1: Activity data per class)

Project year t	Total *ex ante* net baseline carbon stock change		Total *ex post* net actual carbon stock change		Total *ex post* leakage	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e	tCO$_2$-e
0						
1						
2						
. . .						
T						

Where strong evidence can be collected that deforestation in the leakage belt is attributable to deforestation agents that are not linked to the project area, the detected deforestation may not be attributed to the project activity and considered leakage. The operational entity verifying the monitoring data shall determine whether the documentation provided by the project proponent represents sufficient evidence to consider the detected deforestation as not attributable to the project activity and therefore not leakage.

Monitoring of increases in GHG emissions

These must only be estimated and accounted if emissions from forest fires are included in the baseline.

To estimate the increased GHG emissions due to forest fires in the leakage belt area the assumption is made that forest clearing is done by burning the forest. The parameter values used to estimate emissions shall be the same used for estimating forest fires in the baseline (table 18), except for the initial carbon stocks (*Cab*, *Cdw*) which shall be those of the initial forest classes burned in the leakage belt area.

Report the result of the estimations using the same table formats used in the *ex ante* assessment of baseline GHG emissions from forest fires in the project area:

Table 18:   Parameters used to calculate emissions from forest fires in the leakage belt area

Table 19:   *Ex post* estimated non-CO_2 emissions from forest fires in the leakage belt area

1.2.3 Total *ex post* estimated leakage

Summarize the results of all *ex post* estimations of leakage using the same table format used for the *ex ante* assessment:

Table 32.   Total *ex post* estimated leakage.

Note: Monitoring of leakage may become obsolete at the date when a VCS or UNFCCC registered (and VCS endorsed) program is monitoring, reporting, verifying and accounting GHG emissions from deforestation in a broader region encompassing the project area. In such cases, the most recent VCS guidelines on this subject matter shall be applied.

1.3   *Ex post* net anthropogenic GHG emission reductions

The calculation of *ex post* net anthropogenic GHG emission reductions is similar to the e*x ante* calculation with the only difference that *ex post* estimated carbon stock changes and GHG emissions must be used in the case of the project scenario and leakage.

Report the *ex post* estimated net anthropogenic GHG emissions and calculation of Verified Carbon Units (*VCU_t*, and *VBC_t*) using the same table format used for the *ex ante* assessment:

Table 34:   *Ex post* estimated net anthropogenic GHG emission reductions and VCUs**.**

Note: A map showing Cumulative Areas Credited within the project area shall be updated and presented to VCS verifiers at each verification event. The cumulative area cannot generate additional VCUs in future periods.

Task 2: Revisiting the baseline projections for future fixed baseline period

Baselines, independently from the approach chosen to establish them, must be revisited over time because agents, drivers and underlying causes of deforestation change dynamically. Frequent and unpredicted updating of the baseline can create serious market uncertainties. Therefore, the baseline must be revisited only every 10 years. Where an applicable sub-national or national jurisdticational baseline becomes available, baselines may be reassessed earlier in accordance with section 2.2 below. Tasks involved in revisiting the baseline are:

2.1   Update information on agents, drivers and underlying causes of deforestation.

2.2   Adjust the land-use and land-cover change component of the baseline.

2.3   Adjust, as needed, the carbon component of the baseline.

2.1   Update information on agents, drivers and underlying causes of deforestation

Information on agents, drivers and underlying causes of deforestation in the reference region must be collected periodically, as these are essential for improving future deforestation projections and the design of the project activity.

- Collect information that is relevant to understand deforestation agents, drivers and underlying causes.

- Redo step 3 of the *ex ante* methodology at the beginning of each fixed baseline period.

- Where a spatial model was used to locate future deforestation, new data on the spatial driver variables used to model the deforestation risk must be collected as they become available. These must be used to create updated spatial datasets and new "Factor Maps" for the subsequent fixed baseline period.

2.2   Adjustment of the land-use and land-cover change component of the baseline

If an applicable sub-national or national baseline becomes available during the fixed baseline period, it must be used for the subsequent period. Use the criteria of table 2 to assess the applicability of sub-national or national baselines. If VCS requirements on regional baselines are available, use the most recent version of these guidelines instead of table 2.

If an applicable sub-national or national baseline is not available, the baseline projections must be revisited and adjusted as necessary.

The two components of the baseline projections that must be reassessed are:

2.2.1   The annual areas of baseline deforestation; and

2.2.2   The location of baseline deforestation.

2.2.1 Adjustment of the annual areas of baseline deforestation

At the end of each fixed baseline period, the projected annual areas of baseline deforestation for the reference region need to be revisited and eventually adjusted for the subsequent fixed baseline period. The adjusted baseline rates must be submitted to an independent validation.

Adjustments must be made using the methods described in part 2 of the methodology and using the data obtained from monitoring LU/LC changes in the reference region during the past fixed baseline period, updated information on deforestation agents, drivers and underlying cases of deforestation and, where applicable, any updated information on the variables included in the estimation of the projected areas of baseline deforestation.

2.2.2 Adjustment of the location of the projected baseline deforestation

Using the adjusted projections for annual areas of baseline deforestation and any improved spatial data for the creation of the factor maps included in the spatial model, the location of the projected baseline deforestation must be reassessed using the methods explained in part 2 of the methodology.

All areas credited for avoided deforestation in past fixed baseline periods must be excluded from the revisited baseline projections as these areas cannot be credited again. To perform this exclusion use the map of "cumulative areas credited" that was updated in all previous verification events.

Note: If the boundary of the leakage belt area was assessed using equation (1) or any other spatial model, the boundary of the leakage belt will have to be reassessed at the end of each fixed baseline period using the same methodological approaches used in the first period. This will be required until monitoring of leakage will become unnecessary[52].

2.3   Adjustment of the carbon component of the baseline

Adjusting the carbon component of the baseline will not be necessary in most cases (see section 1.1.3 in Part 3 for more detailed guidance). However, improved carbon stock data are likely to become available over time and if this is the case, they must be used when revisiting the baseline projections. Methods to measure and estimate carbon stocks are described in appendix 3.

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[52] Monitoring of leakage will become obsolete at the date when a VCS or UNFCCC registered (and VCS endorsed) program is monitoring, reporting, verifying and accounting emissions from deforestation in a broader area encompassing the project area.

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APPENDIX 1:
Definition of terms frequently used in the methodology

Activity Data is the annual area (ha yr^{-1}) lost or acquired by a *LU/LC class cl* at a given year *t* or the annual area of a *category of LU/LC change ct* for a given year *t*.

Baseline Scenario is the expected change in land use and land cover (LU/LC) in the absence of any *project activity* designed to reduce emissions from *deforestation, forest degradation*, or enhance *carbon stocks*.

Baseline is the sum of *carbon stock* changes and GHG emissions hat would occur in the absence of the proposed REDD *project activity*.

Broad Category is the term used in this methodology to identify three main *categories* of LU/LC-change: *deforestation*, *forest degradation* (with carbon stock decrease) and *forest regeneration*(with carbon stock increase) (see figure A1-1):

Figure A1-1. ***Broad categories*** **of land-use and land-cover change**
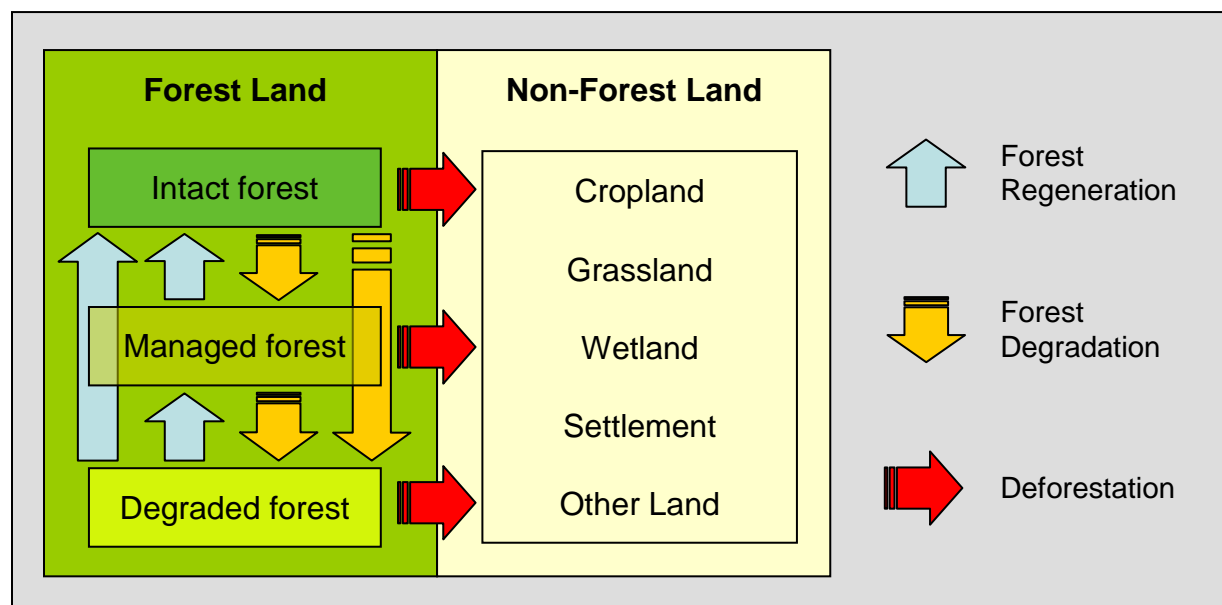
Carbon Density (or *carbon stock* per hectare) is the amount of carbon (as CO_2 e) per hectare (ha^{-1}) estimated to be present in the accounted carbon pools of a *LU/LC Class* at year *t*.

Carbon Stock is the *carbon density* of an area times the number of hectares in the area.

Carbon Stock Change Factor: see "*Emission Factor*".

Category of LU/LC-Change (or simply "*category*") is the change from one *LU/LC class* to another that occurs during a given period of time.

Category is the term used in IPCC reports to refer to specific sources of emissions or removals of greenhouse gases. Under the AFOLU sector, "categories" are land-use /

land-cover (LU/LC) transitions. REDD methodologies deal with the following categories:

(a) *Forest* Land to *Forest* Land (degradation and regeneration of *forest* land remaining *forest* land)

(b) *Forest* Land to Crop Land (*deforestation* followed by agriculture)

(c) *Forest* Land to Grass Land (*deforestation* followed by pasture)

(d) *Forest* Land to Settlements (*deforestation* followed by settlements)

(e) *Forest* Land to Wetlands (*deforestation* followed by wetlands)

(f) *Forest* Land to Other Land (*deforestation* followed by other land)

Activities that convert non *forest* land back to *forest* (Crop Land to *Forest* Land, Grass Land to *Forest* Land, etc.) are considered afforestation and reforestation and are excluded from this REDD methodology.

Class. See *LU/LC Class*.

Project crediting period. Please see current VCS definition.

Deforestation is the direct, human-induced and long-term (or permanent) conversion of *forest* land to non-*forest* land[53]. It occurs when at least one of the parameter values used to define "*forest* land" is reduced from above the threshold for defining "*forest*" to below this threshold for a period of time that is longer than the period of time used to define "*temporarily un-stocked*"[54]. For example, if a country defines a *forest* as having a crown cover greater than 30% and "*temporarily un-stocked*" as a maximum period of 3 years, then *deforestation* would not be recorded until the crown cover is reduced below 30% for at least three consecutive years[55]. Country should develop and report criteria by which temporary removal or loss of tree cover can be distinguished from *deforestation*.

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[53] Forest area and carbon stock losses due to natural disturbances (landslides, consequences of volcanic eruptions, and see level rise, among other) are not considered "deforestation".

[54] According to IPCC (GPG LUUCF, 2003, Chapter 4.2.6.2.) "The identification of units of land subject to deforestation activities requires the delineation of units of land that:
(a) Meet or exceed the size of the country's minimum forest area (i.e., 0.05 to 1 ha); and
(b) Have met the definition of forest on 31 December 1989; and
(c) Have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced deforestation."

[55] Deforestation can be the result of an abrupt event (deforestation = forest → non-forest), in which case the change in land-cover and land-use occurs immediately and simultaneously; or of a process of progressive degradation (deforestation = forest → degraded forest → non-forest), in which case the change in land-cover occurs when one of the parameters used for defining "forest land" falls below its minimum threshold, but the change in land-use may have already occurred or will occur later (e.g. use of the land for the production of crops or grazing animals). Land-use is thus not a reliable indicator for identifying a forest class or for defining a category of change. .

Eligible Land. To avoid double counting of emission reductions, land areas registered under the CDM or the VCS or any other carbon trading scheme (both voluntary and compliance-oriented) should be transparently reported and excluded from the *project area*.

Emission Factor (or *Carbon Stock Change Factor*) is the difference between the *carbon density* of the two *LU/LC classes* describing a *category of LU/LC change*.

Fixed baseline period is the period of time for which the validated *baseline* is fixed, which under the VCS can be up to 10 years. After this period of time, the baseline must be reassessed using a VCS approved methodology.

Forest is a land with woody vegetation consistent with the thresholds used to define "*forest* land" in the country where the REDD *project activity* will be implemented. Where the country has adopted a *forest* definition for the Kyoto Protocol, the minimum thresholds of the vegetation indicators (minimum area, tree crown cover and height)[56] used for defining "*forests*", as communicated by the DNA[57] consistent with decision 11/CP.7 and 19/CP.9, should be used. Otherwise, the definition used to define "*Forest* Land" in national GHG inventory should be used.

Land defined as "*forest* land" can include areas that do not, but at maturity *in situ* could potentially reach, the thresholds used to define "*forest* land". To distinguish between "non-*forest*" (and hence "deforested") and "*temporarily un-stocked*" areas in managed *forests*, the definition of "*forest*" should include the maximum period of time that the woody vegetation can remain below the thresholds used to define "*forest* land". This maximum period can be specific for each *category of land-use / land-cover change (LU/LC-change)*. For instance, it could be zero years for conversion from "*forest* land to crop land", but up to 5 or more years for transitions between *forest* classes (e.g. age classes)[58].

Areas covered with planted *forests* as well as with any other anthropogenic vegetation type that meet the definition of "*forest*" since the earliest date of the *historical reference period* used to assess *deforestation* can be considered "*forest* land". Hence, "*forests*" can be natural, semi-natural, or anthropogenic and they may include primary

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[56] "Forest is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 per cent with trees with the potential to reach a minimum height of 2 – 5 meters at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10 – 30 per cent or tree height of 2 – 5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest".

[57] DNA = Designated National Authority of the Clean Development Mechanism

[58] Project proponents should report on how they distinguish between deforestation and areas that remain forests but where tree cover has been removed temporarily, notably areas that have been harvested or have been subject to other human or natural disturbance but for which it is expected that forest will be replanted or regenerate naturally. See IPCC GPG LULUCF, 2003, Chapter. 4.2.6.2.1 for further guidance on this issue.

or old-growth *forests* (intact or logged), secondary *forests*, planted *forests*, agro-forestry and silvo-pastoral systems.

Forest degradation is "*forest* land remaining *forest* land" but gradually losing *carbon stocks* as a consequence of direct-human intervention (e.g. logging, fuel-wood collection, fire, grazing, etc.)[59]. Units of *forest* land subject to degradation are allocated to different *forest classes* over time, with each successive *class* having a lower *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two contiguous *forest classes* in the degradation sequence (figure A1-2).

Forest management. Areas subject to sustainable *forest management* (with logging activities) represent a particular *class* of "degraded *forest*". An undisturbed natural *forest* that will be subject to sustainable *forest management* will lose part of its carbon, but the loss will partially recover over time. In the long-term, a sustainable harvesting and re-growth cycle will maintain a constant average *carbon density* in the *forest*. Since this average *carbon density* is lower than in the original *forest*, sustainably managed *forests* can be considered a degraded *forest class*.

Depending on the magnitude and timeframe of the *carbon stock* changes, managed *forests* could be classified into one single "managed *forest*" *class* (with a *carbon density* equivalent to the average of the entire management cycle) or to different sub-*classes* representing different average carbon densities (figure A1-2).

Forest Regeneration is "*forest* land remaining *forest* land" but gradually enhancing its carbon stock as a consequence of direct-human intervention. Units of *forest* land subject to regeneration are allocated to different *forest classes* over time, with each successive *forest* class having a higher *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two *forest classes*.

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[59] According to IPCC GPG LLUCF "forest degradation" is "a direct, human-induced, long-term (persisting for *X* years or more) or at least *Y%* of forest carbon stock [and forest values] since time *T* and not qualifying as deforestation". Note that *X*, *Y%* and *T* are not quantified. See IPCC 2003 (Report on Definitions and Methodological Options to Inventory Emissions from Direct Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, Chapter 2.2) for a discussion on the definition of "forest degradation", in particular table 2.1 for alternative definitions of direct human-induced forest degradation.

Figure A1-2. *Carbon density* **in "*forest* land remaining *forest* land" (living tree biomass)**
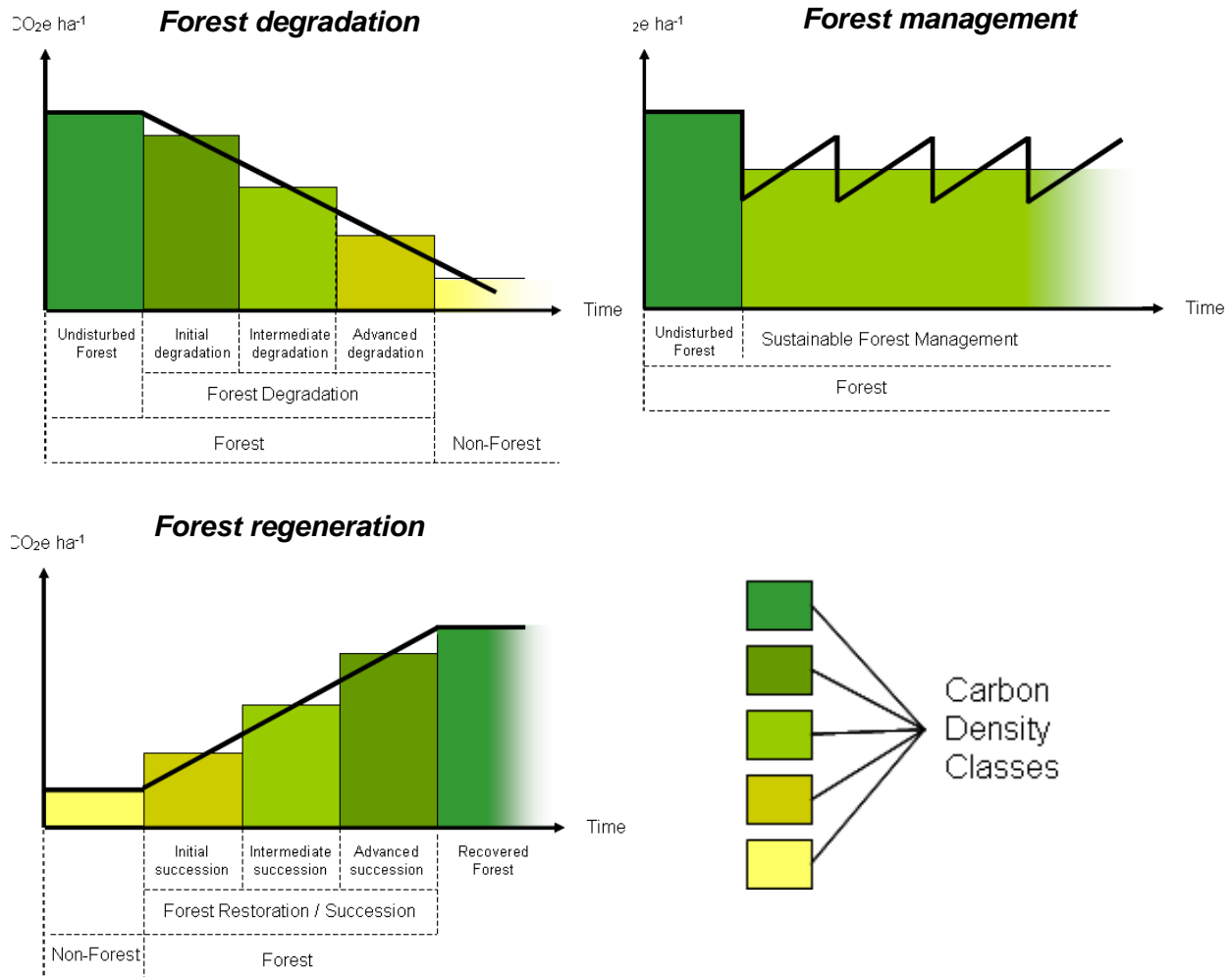
Frontier Deforestation is the conversion of *forest* land to non-*forest* land occurring when the agricultural frontier expands as a result of improved access to *forest* into areas with relatively little human activity.

Historical Reference Period is a time period preceding the starting date of the proposed REDD project activity. It is analyzed to determine the magnitude of *deforestation* and *forest degradation* in the *reference region* and to identify agents and drivers of DD and the chain of events leading to land-use / land-cover change. In order to be useful for understanding recent and likely future DD trends, the starting date of the *historical reference period* should be selected between 10 and 15 years in the past, and the end date as close as possible to present.

Leakage is the decrease in *carbon stocks* and the increase in GHG emissions attributable to the implementation of the REDD *project activity* that occurs outside the boundary of the *Project area*.

Leakage Belt is the geographical area surrounding or adjacent to the *project area* which activity displacement *leakage* could occur.

Leakage Management Area(s) are areas outside the *project area* in which activities are implemented to avoid *leakage.* At the project start date, leakage management areas must be non-forest land

LU/LC Class (or simply "*class*") is a unique combination of land use and land cover having a specific *carbon density* at time *t*.

LU/LC Polygon is a discrete area falling into a single *LU/LC class*.

Monitoring period is the period of time (in years) between two monitoring and verification events. Typically it is a fraction of the *fixed baseline period*. The minimum duration is one year and the maximum is the duration of the *fixed baseline period*.

Mosaic Deforestation is the conversion of *forest* land to non-*forest* land occurring in a patchy pattern where human population and associated agricultural activities and infrastructure (roads, towns, etc) are spread out across the landscape and most areas of *forest* within such a configured region or country are practically already accessible.

Planned Deforestation is the legally authorized conversion of *forest* land to non-*forest* land occurring in a discrete area of land. *Deforestation* within an area can be planned (designated and sanctioned) or unplanned (unsanctioned). *Planned deforestation* can include a wide variety of activities such as national resettlement programs from non-forested to forested regions; a component of a national land plan to reduce the *forest* estate and convert it to other industrial-scale production of goods such as soybeans, pulpwood plantations, and oil palm plantations; or plans to convert well-managed community-owned *forests* to other non-*forest* uses. Other forms of *planned deforestation* could also include decisions by individual land owners, whose land is legally zoned for agriculture, to convert their say selectively logged *forest* to crop production. These *planned deforestation* activities would be a component of some land planning or management document and could be readily verified.

Project Activity is the series of planned steps and activities by which the proponent intends to reduce *deforestation* and *forest degradation* and/or enhance forest regeneration.

Project area is the area or areas of land on which the proponent will undertake the *project activities*. No lands on which the *project activity* will not be undertaken can be included in the *project area*.

Project Scenario is the expected change in land use and land cover within the boundary of the *project area* resulting from the undertaking of the *project activity*.

Project Term is the projected lifetime of the REDD *project activity*, which under the VCS is equivalent to the project *crediting period*.

Reference region is the spatial delimitation of the analytic domain from which information about *deforestation* and degradation agents, drivers and LU/LC-change is obtained, projected into the future and monitored. The *reference region* includes the *Project*

area[60] and is defined by the project proponent using transparent criteria. It must contain *LU/LC classes* and *deforestation* agents and drivers similar to those found in the *project area* under the *baseline* and *project scenarios*.

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[60]   The methodology thus adopts a so called "Stratified Regional Baseline" (SRB) approach, which has been recommended in recent literature (Sataye and Andrasko, 2007; Brown *et al.*, 2007)

APPENDIX 2:
Indicative tables

Table 1. Guidance on carbon pool selection depending on the land-use / land-cover change *category* considered[61]

Type of land-use / land-cover transition	Living biomass (trees)		Dead organic matter			Soil
	Above-ground	Below-ground	Wood products	Dead wood	Litter	Organic matter
Forest to cropland	+++	++	+	+	+	+
Forest to pasture	+++	++	+	+	+	
Forest to shifting cultivation	+++	++		+		
Forest to degraded *forest*	+++	++	+			
+++ = include always; ++ = inclusion recommended; + = inclusion possible						

Table 2. Present availability of optical mid-resolution (10-60m) sensors
(GOFC-GOLD, 2008)

Nation	Satellite & sensor	Resolution & coverage	Cost (archive[62])	Feature
U.S.A.	Landsat-5 TM	30 m 180×180 km^2	600 US$/scene 0.02 US$/km^2	Images every 16 days to any satellite receiving station. Operating beyond expected lifetime.
U.S.A.	Landsat-7 ETM+	30 m 60×180 km^2	600 US$/scene 0.06 US$/km^2	On April 2003 the failure of the scan line corrector resulted in data gaps outside of the central portion of images, seriously compromising data quality
U.S.A./Japan	Terra ASTER	15 m 60×60 km^2	60 US$/scene 0.02 US$/km^2	Data is acquired on request and is not routinely collected for all areas
India	IRS-P2 LISS-III & AWIFS	23.5 & 56 m		Experimental craft shows promise, although images are hard to acquire
China/Brazil	CBERS-2 HRCCD	20 m		Experimental; Brazil uses on-demand images to bolster their coverage.
Algeria/China/Nigeria/Turkey/U.K.	DMC	32 m 160×660 km^2	3000 €/scene 0.03 €/km^2	Commercial; Brazil uses alongside Landsat data
France	SPOT-5 HRVIR	5-20 m 60×60 km^2	2000 €/scene 0.5 €/km^2	Commercial Indonesia & Thailand used alongside Landsat data

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[61] Modified from GOFC-GOLD, 2008. See the most recent version of the GOFC-GOLD sourcebook for REDD, as new remote sensing platforms are becoming available.

[62] Some acquisitions can be programmed (e.g., DMC, SPOT). The cost of programmed data is generally at least twice the cost of archived data.

Table 3. Example of a potential land use-change matrix

Initial / Final		Forest land				
		Class 1	Class 2	Class 3	Class 4	Class 5
Forest Land	Class 1	Category 1/1	Category 2/1	Category 3/1	Category 4/1	Category 5/1
	Class 2	Category 1/2	Category 2/2	Category 3/2	Category 4/2	Category 5/2
	Class 3	Category 1/3	Category 2/3	Category 3/3	Category 4/3	Category 5/3
	Class 4	Category 1/4	Category 2/4	Category 3/4	Category 4/4	Category 5/4
	Class 5	Category 1/5	Category 2/5	Category 3/5	Category 4/5	Category 5/5
Grassland	Class 6	Category 1/6	Category 2/6	Category 3/6	Category 4/6	Category 5/6
Cropland	Class 7	Category 1/7	Category 2/7	Category 3/7	Category 4/7	Category 5/7
Wetland	Class 8	Category 1/8	Category 2/8	Category 3/8	Category 4/8	Category 5/8
Settlement	Class 9	Category 1/9	Category 2/9	Category 3/9	Category 4/9	Category 5/9
Other Land	Class 10	Category 1/10	Category 2/10	Category 3/10	Category 4/10	Category 5/10

Table 4. Example of a land-use / land-cover change matrix

Initial / Final			Old growth forests		Degraded old growth forest			Secondary forest			Plantations			Final area
			intact	managed	initial	intermediate	advanced	initial	intermediate	advanced	young	mid	mature	
Forest Land	Old-growth	intact	100											**100**
		managed	1	5										**6**
	Degraded	initial	1		2									**3**
		intermediate			2	1								**3**
		advanced				2	3							**5**
	Secondary	initial						2						**2**
		intermediate						1	3					**4**
		advanced							1	1				**2**
	Plantations	young						1	1	1	1		1	**5**
		mid									1	2		**3**
		mature											1	**1**
Grassland		unimproved	1	1	1	2		1	1	1				**8**
		improved				1	1							**2**
Cropland				1		1		2	3	3				**10**
Wetland														**0**
Settlement														**0**
Other Land														**0**
Initial Area			**103**	**7**	**5**	**7**	**5**	**7**	**9**	**5**	**2**	**2**	**2**	**154**
Net Change			-3	-1	-2	-4	0	-5	-5	-3	3	1	-1	0

Notes:

- Numbers represent hectares or *activity data* (in this case numbers are for illustrative purposes only, they do not represent any real case).
- Column and rows totals show net conversion of each LU/LC-class.

- "Initial" indicates the area of the LU/LC-class at the starting date of the period assessed, and "Final" the area of the class at the end date of the assessment period.
- Net changes (bottom rows) are the final area minus the initial area for each of the LU/LC-classes shown at the head of the corresponding column.
- Blank entries indicate no LU/LC-change the period assessed.

Table 5. Approximate values of daily biomass intake (d. m. – dry mass) for different type of animals[63]

Animal Type		Daily Feed Intake (MJ head^{-1} day^{-1})	Daily Biomass Intake (kg d. m. head^{-1} day^{-1})
Sheep	Developed Countries	20	2.0
	Developing Countries	9	1.3
Goats	Developed Countries	14	1.4
	Developing Countries	14	1.4
Mules/Asses	Developed Countries	60	6.0
	Developing Countries	60	6.0
Sources: Feed intake from Crutzen *et al.* (1986).			

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[63] Taken form AR-AM0003 version 2

Box 1: Geomod

Geomod is a land-use land-cover change simulation model implemented in Idrisi, a GIS software developed by Clark University (Pontius *et al.*, 2001; Brown *et al.*, 2007). Geomod has been used frequently to analyze baseline scenarios of deforestation at continental scale for Africa, Asia and Latin America; at the country scale for Costa Rica and India; and at local scale within India, Egypt, Unites States and several countries in Latin America (Pontius and Chen, 2006).

Geomod is a grid-based model that predicts the transition from one *LU/LC class* to another *LU/LC class*, i.e. the location of grid cells that change over time from *class* 1 to *class* 2. Hence, Geomod can be used to predict areas likely to change from *forest class* 1 to non-forest *class* 2 (*deforestation*) over a given time.

Geomod creates the LU/LC-change risk map empirically, by using several driver images and the land-cover map from the beginning time. For example, Geomod's *deforestation* risk maps have relatively high values at location that have biogeophysical attributes similar to those of the deforested land (= "developed land" in Geomod's jargon) of the beginning time, and has relatively low values at locations that have biogeophysical attributes similar to those of forested land ("non-developed" land) of the beginning time.

APPENDIX 3:
Methods to estimate carbon stocks

Sampling framework

The sampling framework, including sample size, plot size, plot shape and plot location should be specified in the PD.

Areas to be sampled in forest classes should be at locations expected to be deforested according to the baseline projections.

The sampling areas for non-forest classes should be selected within the reference region at locations that represent a chrono-sequence of 10 to 30 years since the deforestation date.

Temporary or permanent plots

Plots can be temporary or permanent depending on the specific project circumstances, interests and needs, but in general temporary plots should be sufficient.

Where changes in carbon stocks are to be monitored, permanent sampling plots are recommended. Permanent sample plots are generally regarded as statistically efficient in estimating changes in forest carbon stocks because typically there is high covariance between observations at successive sampling events. However, it should be ensured that the plots are treated in the same way as other lands within the project boundary, e.g., during logging operations, and should not be destroyed over the monitoring interval. Ideally, staff involved in forest management activities should not be aware of the location of monitoring plots. Where local markers are used, these should not be visible. If trees markers are required (e.g. if plots are also used for ecological or structural monitoring), these should be as unconspicous as possible and no bias in the treatment of plots compared to the surrounding forest must be granted.

Permanent plots may also be considered to reduce the uncertainty of the average carbon density of a forest class undergoing carbon stock changes due to management and to detect changes in carbon stocks induced by climate change or large-scale natural disturbances.

Definition of the sample size and allocation among LU/LC-classes

The number of sample plots is estimated as dependent on accuracy, variability of the parameter to estimate in each class and costs. The sample size calculation also corresponds to the method of samples drawn without replacement. Where at the beginning of a REDD project activity accurate data for sample size estimation and allocation are not available, the sampling size can initially be estimated by using a desired level of accuracy (10% of sampling error at 95% confidence level), and by allocating the estimated sample size proportionally to the area of each class[64], using respectively equations 1, and 2. Then, once data on carbon stock

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[64] Loetsch, F. and Haller, K. 1964. Forest Inventory. Volume 1. BLV-VERLAGS GESE LLSCHAFT, München.

variability within each class become available, the sample size and allocation is recalculated using the methodology described by Wenger (1984)[65], which also accounts for the cost of sampling (see equations 3 and 4).

Equation 1 was chosen because it works with percentages rather than absolute units (biomass, carbon, or CO_2), and coefficient variation data could be more easy to find in the literature at the beginning of a project activity. The initial allocation of the sample plots shall be proportional to the area of the LU/LC-classes, but with minimum of 5 plots per class. The t-student for a 95% confidence level is approximately equal to 2 when the number of sample plot is over 30. As the first step, use 2 as the t –student value, and if the resulting "*n*" is less than 30, use the new "*n*" to get a new t-student value and conduct the new estimation of the sample size. This process can be repeated until the calculated *n* is stabilized.

$$n = \frac{t_{st}^2 \cdot (CV\%)^2}{(E\%)^2 + \frac{t_{st}^2 \cdot (CV\%)^2}{N}} \qquad (A3\text{-}1)$$

$$n_{cl} = n \cdot \frac{N_{cl}}{N} \qquad (A3\text{-}2)$$

Where:

cl	=	1, 2, 3, …. *Cl* LU/LC classes
Cl	=	Total number of LU/LC classes
t_{st}	=	t-student value for a 95% confidence level (initial value t = 2)
n	=	total number of sample units to be measured (in all LU/LC classes)
E%	=	allowable sample error in percentage (±10%)
CV%	=	the highest coefficient of variation (%) reported in the literature from different volume or biomass forest inventories in forest plantations, natural forests, agro-forestry and/or silvo-pastoral systems.
n_i	=	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to the size of the class. If estimated $n_{cl} < 3$, set $n_{cl} = 3$.
N_i	=	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of *class cl* by the measurement plot area.
N	=	population size or maximum number of possible sample units (all LU/LC classes), $N = \sum_{cl=1}^{Cl} N_{cl}$

In equation A3-2 the standard deviation of each LU/LC class (S_{cl}) shall be determined using the actual data from the latest field measurement. The allowable error is an absolute value, and can be estimated as ±10% of the observed overall average carbon stock per hectare. It is

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[65] Wenger, K.F. (ed). 1984. Forestry handbook (2nd edition). New York: John Wiley and Sons.

possible to reasonably modify the LU/LC class limits and the sample size after each monitoring event based on the actual variation of the carbon stock changes determined from taking "n" sample plots. Where costs for selecting and measuring plots are not a significant consideration then the calculation and allocation of the sample size can be simplified by setting C_{cl} equal to 1 across all LU/LC classes.

$$n = \left(\frac{t_{st}}{E}\right)^2 \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \cdot \sqrt{C_{cl}}\right] \cdot \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}} \cdot\right] \tag{A3-3}$$

$$n_{cl} = n \cdot \frac{W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}}}{\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}}} \tag{A3-4}$$

Where:

cl	=	1, 2, 3, … Cl LU/LC classes
Cl	=	total number of LU/LC classes
t_{st}	=	t-student value for a 95% confidence level, with n-2 degrees of freedom
E	=	allowable error (±10% of the mean)
S_{cl}	=	standard deviation of LU/LC class cl
n_{cl}	=	number of samples units to be measured in LU/LC class cl that is allocated proportional to $W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}}$. If $n_{cl} < 3$, set $n_{cl} = 3$.
W_{cl}	=	N_{cl}/N
n	=	total number of sample units to be measured (in all LU/LC classes)
N_{cl}	=	maximum number of possible sample units for LU/LC class cl, calculated by dividing the area of LU/LC class cl by the measurement plot area
N	=	population size or maximum number of possible sample units (all strata), $$N = \sum_{cl=1}^{Cl} N_{cl}$$
C_i	=	cost to select and measure a plot of the LU/LC class cl

Sample plot size

The plot area a has major influence on the sampling intensity, time and resources spent in the field measurements. The area of a plot depends on the stand density. Therefore, increasing the plot area decreases the variability between two samples. According to Freese (1962)[66], the relationship between coefficient of variation and plot area can be denoted as follows:

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[66]   Freese, F. 1962. Elementary Forest Sampling. USDA Handbook 232. GPO Washington, DC. 91 pp

$$CV_2{}^2 = CV_1{}^2 \sqrt{(a_1/a_2)} \qquad \text{(A3-5)}$$

Where a_1 and a_2 represent different sample plot areas and their corresponding coefficient of variation (*CV*). Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same precision level. Usually, the size of plots is between 100 m^2 for dense stands and 1000 m^2 for open stands[67].

Plot location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more "convenient" positions), the permanent sample plots shall be located either systematically with a random start (which is considered good practice in IPCC GPG-LULUCF) or completely randomly inside each defined stratum. This can be accomplished with the help of the project GIS platform and a GPS in the field. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plot, as well as the procedure used for locating them shall be recorded and archived.

Also, it is recommended that the sampling plots are as evenly distributed as possible. For example, if one stratum consists of three geographically separated sites, then it is proposed to

- Divide the total stratum area by the number of plots, resulting in the average area represented by each plot;

- Divide the area of each site by this average area per plot, and assign the integer part of the result to this site. e.g., if the division results in 6.3 plots, then 6 plots are assigned to this site, and 0.3 plots are carried over to the next site, and so on.

However, remote areas and areas with poor accessibility (either because of physical or social barriers such as unsafe areas) may be excluded for the location of sampling plots, using a transparent and conservative procedure, such as creating a buffer zone along roads, paths or navigable rivers that may be used for reaching the sampling plots. In this case, the representativeness of the plots for the corresponding stratum must be ensured.

The exact total number of plots is unknown at the beginning of the field sampling and thus a perfectly even distribution of sampling plots is not possible. This is also the case if pre existing inventory data is used. In any case, the uneven distribution of sampling plots will be accepted provided that statistical representativeness and the use of standard sampling techniques are granted, clearly reported and archived.

Estimation of carbon stocks

The total average carbon stock per hectare (= carbon density) in a LU/LC class is estimated by the following equation:

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[67] It is recommended to use sample plots of equal area for the strata. This methodology cannot be used if sample plots area varies within the same stratum. The density of trees to be considered is the one at maturity of the trees.

$$Ctot_{cl} = Cab_{cl} + Cbb_{cl} + Cdw_{cl} + Cl_{cl} + Csoc_{cl} - Cwp_{cl} \qquad \text{(A3-6)}$$

Where:

$Ctot_{cl}$ = Average carbon stock per hectare in all accounted carbon pools of the LU/LC-class cl; $tCO_2\text{-}e\ ha^{-1}$

Note: Cwp_{cl} is <u>subtracted</u> if cl is an initial pre-deforestation forest class in the baseline case. It is added if cl is a final post-deforestation class or a forest class not deforested in the project scenario.

Cab_{cl} = Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class cl; $tCO_2\text{-}e\ ha^{-1}$

Cbb_{cl} = Average carbon stock per hectare in the below-ground biomass carbon pool of the *LU/LC class cl*; $tCO_2\text{-}e\ ha^{-1}$

Cdw_{cl} = Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class cl; $tCO_2\text{-}e\ ha^{-1}$

Cl_{cl} = Average carbon stock per hectare in the litter carbon pool of the LU/LC class cl; $tCO_2\text{-}e\ ha^{-1}$

$Csoc_{cl}$ = Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class cl; $tCO_2\text{-}e\ ha^{-1}$

Cwp_{cl} = Average carbon stock per hectare in the wood products carbon pool of the LU/LC class cl;

Note: See methodology Part 2 on mandatory carbon pools.

Estimation of carbon stocks in the living biomass carbon pools (Cab_{cl} and Cbb_{cl})

In a forest most of the carbon is stored in the tree component of the living biomass. Hence, for a majority of forest classes it is sufficient to estimate the carbon stock in the tree component and to ignore the carbon stock in the non-tree vegetation component.

However, there might be situations where carbon stocks in the non-tree vegetation component are significantly increased in the LU/LC-classes adopted after deforestation (e.g. coffee plantations). Under such circumstances, carbon stocks in the non-tree vegetation component should be estimated[68].

The living biomass components that are measured and the minimum diameter at breast height (DBH) above which trees are measured should be specified in the PD.

Carbon stocks in the living biomass are given by the following equations:

$$Cab_{cl} = Cabt_{cl} + Cabnt_{cl} \qquad\qquad (A3\text{-}7)$$

$$Cbb_{cl} = Cbbt_{cl} + Cbbnt_{cl} \qquad\qquad (A3\text{-}8)$$

Where:

Cab_{cl}	=	Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$
$Cabt_{cl}$	=	Average *carbon stock* per hectare in the above-ground tree biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$
$Cabnt_{cl}$	=	Average *carbon stock* per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$
Cbb_{cl}	=	Average *carbon stock* per hectare in the below-ground biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$
$Cbbt_{cl}$	=	Average *carbon stock* per hectare in the below-ground tree biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$
$Cbbnt_{cl}$	=	Average carbon stock per hectare in the below-ground non-tree biomass carbon pool of the LU/LC class *cl*; $tCO_2\text{-e ha}^{-1}$

Tree component ($Cabt_{cl}$ and Cbb_{cl})

The carbon stock of trees can be estimated using: (a) Existing forest inventory data; or (b) Direct field measurements.

(a) Estimations using *forest* inventory data
(See the most recent version of the GOFC-GOLD sourcebook for REDD for more details)

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[68] The same carbon pools are to be estimated for the two classes of a LU/LC-change category

Forest inventory data typically comes in two different forms: (1) Stand tables and (2) Stock tables.

(a.1) <u>Stand tables</u> provide the number of trees in diameter (DBH) classes. The method basically involves estimating the biomass per average tree of each diameter class of the stand table, multiplying by the number of trees in the class, and summing across all classes. The mid-point diameter of a diameter class should be used in combination with an allometric biomass regression equation (explained later).

Stand tables often include trees with a minimum diameter of 30 cm or more, which essentially ignores a significant amount of carbon particularly for younger *forests* or heavily logged. To overcome this problem Gillespie *et al.* (1992) developed a technique that can be used to estimate the number of trees in lower diameter classes (see Box 1).

Box 1. Adding diameter classes to truncated stand tables

DBH-Class	Midpoint Diameter	Number of Stems per ha
cm	cm	Nr
10-19	15	-
20-29	25	-
30-39	35	35.1
40-49	45	11.8
50-59	55	4.7
…	…	…

DBH class 1 = 30-39 cm, DBH class 2 =40-49 cm
Ratio   = 35.1/11.8 =   = 2.97
Therefore, the number of trees in the 20-29 cm class is:
2.97 x 35.1 = 104.4
To calculate the 10-19 cm class:
104.4/35.1 = 2.97,
2.97 x 104.4 = 310.6

(a.2) <u>Stock tables</u> indicate the volume of merchantable timber by diameter class or total per hectare. If volume data are just for commercial species do not use them for estimating *carbon stock*s, because a large and unknown proportion of the total volume is excluded.

The biomass density can be calculated from Volume Over Bark (*VOB*) by multiplying this value with the Biomass Conversion and Expansion Factor (*BCEF*). When using this approach and default values of the *BCEF* provided in the IPCC GL AFOLU, it is important that the definitions of *VOB* match. The values of *BCEF* for tropical *forests* in the AFOLU report are based on a definition of *VOB* as follows:

> *"Inventoried volume over bark of free bole, i.e. from stump or buttress to crown point or first main branch. Inventoried volume must include all trees, whether*

presently commercial or not, with a minimum diameter of 10 cm at breast height or above buttress if this is higher".

Values of the *BCEF* are given in table 4.5 of the IPCC GL AFOLU guidelines, and those relevant to tropical humid broadleaf and pine *forests* are shown in the table 1.

Table 1. Values of *BCEF* for application to volume data
(Modified by GOFC-GOLD (2008) from table 4.5 in IPCC GL AFOLU)

Forest type	Growing stock volume –*average* and range (*VOB*, m^3/ha)						
	<20	21-40	41-60	61-80	80-120	120-200	>200
Natural broadleaf	4.0	2.8	2.1	1.7	1.5	1.3	1.0
	2.5-12.0	1.8-304	1.2-2.5	1.2-2.2	1.0-1.8	0.9-1.6	0.7-1.1
Conifer	1.8	1.3	1.0	0.8	0.8	0.7	0.7
	1.4-2.4	1.0-1.5	0.8-1.2	0.7-1.2	0.6-1.0	1.6-0.9	0.6-0.9

In cases where the definition of *VOB* does not match exactly the definition given above, GOFC-GOLD (2008) recommend the following:

- If the definition of *VOB* also includes stem tops and large branches then the lower bound of the range for a given growing stock should be used;

- If the definition of *VOB* has a large minimum top diameter or the *VOB* is comprised of trees with particularly high basic wood density then the upper bound of the range should be used.

Forest inventories often report volumes for trees above a minimum *DBH*. To include the volume of *DBH* classes below the minimum *DBH*, GOFC-GOLD (2008) proposes Volume Expansion Factors (*VEF*). However, due to large uncertainties in the volume of smaller *DBH* classes, inventories with a minimum diameter that is higher than 30 cm should not be used. Volume expansion factors range from about 1.1 to 2.5, and are related to the *VOB*30 as follows to allow conversion of *VOB*30 to a *VOB*10 equivalent:

- For *VOB*30 < 250 m^3/ha use the following equation:

$$VEF = Exp(1.300 - 0.209 * \ln(VOB30)) \tag{A3-9}$$

- For *VOB*30 > 250 m^3/ha use *VEF* = 1.9

See Box 2 for a demonstration of the use of the *VEF* correction factor and *BCEF* to estimate biomass density.

Box 2. Use of volume expansion factor (*VEF*) and biomass conversion and expansion factor (*BCEF*)

Tropical broadleaf *forest* with a VOB30 = 100 m^3/ha

(1) Calculate the *VEF*:
     VEF = Exp(1.300 - 0.209*Ln(100)) = 1.40

(2) Calculate *VOB*10:
     *VOB*10 = 100 m^3/ha x 1.40 = 140 m^3/ha

(3) Take the *BCEF* from the table 1 above:
     BCEF for tropical hardwood with growing stock of 140 m^3/ha = 1.3

(4) Calculate above-ground biomass density:
     = 1.3 x 140 = 182 t/ha

Below-ground tree biomass (roots) is almost never measured, but instead is included through a relationship to above-ground biomass (usually a root-to-shoot ratio). If the vegetation strata correspond with tropical or subtropical types listed in table 2 (modified by GOFC-GOLD, 2008 from table 4.4 in IPCC GL AFOLU to exclude non-*forest* or non-tropical values and to account for incorrect values) then it makes sense to include roots.

Table 2. Root to shoot ratios

(Modified[69] by GOFC-GOLD, 2008) from table 4.4 in IPCC GL AFOLU)

Domain	Ecological Zone	Above-ground biomass	Root-to-shoot ratio	Range
Tropical	Tropical rain*forest*	<125 t.ha^{-1}	0.20	0.09-0.25
		>125 t.ha^{-1}	0.24	0.22-0.33
	Tropical dry *forest*	<20 t.ha^{-1}	0.56	0.28-0.68
		>20 t.ha^{-1}	0.28	0.27-0.28
Subtropical	Subtropical humid *forest*	<125 t.ha^{-1}	0.20	0.09-0.25
		>125 t.ha^{-1}	0.24	0.22-0.33
	Subtropical dry *forest*	<20 t.ha^{-1}	0.56	0.28-0.68
		>20 t.ha^{-1}	0.28	0.27-0.28

(b)   Estimations using direct field measurements

Two methods are available to estimate the carbon stock of trees: (1) Allometric Equations method, and (2) Biomass Expansion Factors (*BEF*). The Allometric Equations method should be favored over the *BEF* method. However, if no biomass equations are available for a given species or *forest* type, the *BEF* method shall be used.

(b.1) <u>Allometric method</u>

1.   In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly, depending on the form of the allometric equation, the height of all the trees above a minimum *DBH*.

2.   Choose or establish the appropriate allometric equations for each species or species group *j*.

$$TBab_j = f_j(DBH, H)_{ab} \qquad\qquad \text{(A3-10)}$$

Where:

$TBab_j$ = above-ground biomass of a tree of species, or species group, or forest type *j*, kg tree^{-1}

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[69]   The modification corrects an error in the table based on communications with Karel Mulroney, the lead author of the peer reviewed paper from which the data were extracted.

Note: the unit (Kg tree^{-1}) could also be t tree^{-1} or t ha^{-1}, depending on the type of allometric equation

$f_j(DBH,H)_{ab}$ = an allometric equation for species, or group of species, or forest type *j*, linking above-ground tree biomass (in kg tree^{-1} – see the note above) to diameter at breast height (*DBH*) and possibly tree height (*H*).

The allometric equations are preferably local-derived and forest type-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different species and sizes and estimate their biomass and then compare against the selected equation. The number of trees to be felled will depend on the number of species and the range of size of trees the model(s) will represent. As a general rule, there should be two trees sampled for each 5 cm *DBH* width class. In case of mixed species natural forests, the sample should represent all strata existing in the forest. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project; otherwise, it will be required to develop full allometric models valid for the project. In this case, the sample must be increased until obtaining an appropriated statistical fit (all model variables should be statistically significant and the squared r of equation should be at least 0.7). If resources permit, the carbon content can be determined in the laboratory. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as basal area or tree diameter and total height (see Chapter 4.3 in GPG LULUCF). Also generic allometric equations can be used, as long as it can be proven that they are conservative.

3. Estimate the carbon stock in the above-ground biomass of all trees measured in the permanent sample plots using the allometric equations selected or established for each species, group of species or forest type.

$$TCab_{tr} = TBab_{tr} \cdot CF_j \qquad\qquad (A3\text{-}11)$$

Where:

$TCab_{tr}$ = *Carbon stock* in above-ground biomass of tree *tr*; kg C tree^{-1}(or t C tree-^{1})

$TBab_{tr}$ = Above-ground biomass of tree *tr*; kg tree^{-1}(or t tree-^{1})

CF_j = Carbon fraction for tree *tr,* of species, group of species or forest type *j*; t C (t d. m.)$^{-1}$

4. Calculate the carbon stock in above-ground biomass per plot on a per area basis. Calculate by summing the carbon stock in above-ground biomass of all trees within each plot and multiplying by a plot expansion factor that is proportional to the area of the

measurement plot. If carbon stock is calculated in kilograms, it is divided by 1,000 to convert from kg to tonnes.

$$PCab_{pl} = \frac{\left(\sum_{tr=1}^{TR_{pl}} TCab_{tr} \cdot XF \right)}{1000} \tag{A3-12}$$

$$XF = \frac{10,000}{AP} \tag{A3-13}$$

Where:

$PCab_{pl}$ =   Carbon stock in above-ground biomass in plot pl; t C ha^{-1}

$TCab_{tr}$ =   Above-ground biomass of tree tr; kg tree^{-1}(or t tree-^{1})

XF =   Plot expansion factor from per plot values to per hectare values; dimensionless

AP =   Plot area; m^2

tr =   1, 2, 3, … TR_{pl} number of trees in plot pl; dimensionless

5.   Calculate the average carbon stock by averaging across all plots within a LU/LC class.

$$Cab_{cl} = 44/12 * \frac{\sum_{pl=1}^{PL_{cl}} PCab_{pl}}{PL_{cl}} \tag{A3-14}$$

Where:

Ca_{cl} =   Average carbon stock per hectare in above-ground biomass in LU/LC class cl; tCO$_2$-eha^{-1}.

$PCab_{pl}$ =   Carbon stock in above-ground biomass in plot pl; t C ha^{-1}

44/12   =   Ratio converting C to CO$_2$-e

pl =   1, 2, 3, … PL_{cl} plots in LU/LC class cl; dimensionless

PL_{cl} =   Total number of plots in LU/LC class cl; dimensionless

6.   Estimate the carbon stock in the below-ground biomass of tree tr using root-shoot ratios and above-ground carbon stock and apply steps 4 and 5 to below-ground biomass.

$$TCbb_{tr} = TCab_{tr} \cdot R_j \tag{A3-15}$$

$$PCbb_{pl} = \frac{\left(\sum_{tr=1}^{TR} TCbb_{tr} \cdot XF \right)}{1000} \tag{A3-16}$$

$$Cbb_{cl} = \frac{\sum_{pl=1}^{PL_l} PCbb_{pl}}{PL_l} \qquad (A3\text{-}17)$$

Where:

$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree tr; kg C tree^{-1}(or t C tree^{-1})
$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree tr; kg C tree^{-1}(or t C tree^{-1})
R_j	=	Root-shoot ratio appropriate for species, group of species or forest type j; dimensionless
$PCbb_{pl}$	=	Carbon stock in below-ground biomass in plot pl; t C ha^{-1}
XF	=	Plot expansion factor from per plot values to per hectare values
tr	=	1, 2, 3, … TR_{pl} number of trees in plot pl; dimensionless
Cbb_{cl}	=	Average carbon stock per hectare in below-ground biomass in *LU/LC class cl*; tCO$_2$-eha^{-1}
44/12	=	Ratio converting C to CO$_2$-e
pl	=	1, 2, 3, … PL_l plots in LU/LC class cl; dimensionless
PL_{cl}	=	total number of plots in LU/LC class cl; dimensionless

(b.2) Biomass Expansion Factor (*BEF*) Method

1. In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly, depending on the form of the volume equation, the height of all the trees above a minimum *DBH*.

2. Estimate the volume of the commercial component per each tree based on locally derived equations by species, species group or forest type. Then, sum for all trees within a plot, and express it as commercial volume per unit of area (m^3 ha^{-1}). It is also possible to combine step b.1 and step b.2 if there are available field instruments that measure volume per hectare directly (e.g. a Bitterlich relascope). The volume per plot is an ancillary variable, and it may be needed in some cases to estimate the proper biomass expansion factor or the root-shoot ratio.[70]

$$V_{tr} = f_j(DBH, H)_V \qquad (A3\text{-}18)$$

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[70] See for example: Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A primer. FAO Forestry Paper 134, UN FAO, Rome.

$$V_{pl} = \sum_{tr=1}^{TR} V_{tr} \cdot XF \tag{A3-19}$$

$$XF = \frac{10,000}{AP} \tag{A3-20}$$

Where:

V_{tr}	=	Commercial volume of tree tr; m^3 tree^{-1}
V_{pl}	=	Commercial volume of plot pl; m^3 plot^{-1}
$f_j(DBH,H)_V$	=	a commercial volume equation for species or species group j, linking commercial volume to diameter at breast height (DBH) and possibly tree height (H).
tr	=	1, 2, 3, … TR_p number of trees in plot p; dimensionless
XF	=	Plot expansion factor from per plot values to per hectare values
AP	=	plot area; m^2

3.   Choose a biomass expansion factor (*BEF*) and a root-shoot ratio (*R*). The *BEF* and root-shoot ratio vary with local environmental conditions, forest type, species and age of trees, and the volume of the commercial component of trees, therefore, they should be calculated for each plot in a given *LU/LC class*. Use the result from '2' to choose them. These parameters can be determined by either developing a local regression equation or selecting from national inventory, annex 3A.1 table 3A.1.10 of GPG LULUCF, or from published sources.
    If a significant amount of effort is required to develop local *BEFs* and root-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method above (refers to Chapter 4.3 in GPG LULUCF). If that is not possible either, national species specific defaults for *BEF* and *R* can be used. Since both *BEF* and the root-shoot ratio (*R*) are age or stand density dependent, it is desirable to use age-dependent or stand density-dependent equations (for example, volume per hectare). Stem wood volume can be very small in young stands and *BEF* can be very large, while for old stands *BEF* is usually significantly smaller. Therefore using average *BEF* value may result in significant errors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent or stand density-dependent *BEFs* (but for very young trees, multiplying a small number for stem wood with a large number for the *BEF* can result in significant error).

4.   Convert the volume of the commercial component of each tree in a plot into carbon stock in above-ground biomass and below-ground biomass per tree via basic wood density, BEF, root-shoot ratio and carbon fraction (applicable to the species):

$$TCab_{tr} = V_{tr} \cdot D_j \cdot BEF_{pl} \cdot CF_j \tag{A3-21}$$

$$TCbb_{tr} = TCab_{tr} \cdot R_{j,pl,tr} \qquad\qquad (A3\text{-}22)$$

Where:

$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree tr; kg C tree^{-1}
$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree tr; kg C tree^{-1}
V_{tr}	=	Commercial volume of tree tr; m^3 tree^{-1}
D_j	=	Wood density for species j; tonnes d. m. m^{-3} (See IPCC GPG-LULUCF, 2003 table 3A.1.9 or USDA wood density table[71])
BEF_{pl}	=	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree tr, in plot p; dimensionless.
CF_j	=	Carbon fraction applicable to tree tr of species j; tonnes C (tonne d. m.)$^{-1}$.
$R_{j,pl,tr}$	=	Root-shoot ratio, applicable to tree tr of species j in plot p; dimensionless

5. Continue with step a.4 of the allometric equation method to calculate the *carbon stock* in above-ground and below-ground biomass by aggregating successively at the tree, plot, and *LU/LC class* levels.

Non-tree component (*Cabnt*$_{cl}$ and *Cbbnt*$_{cl}$)

In tropical forests non-tree vegetation includes palms, shrubs, herbaceous plants, lianas and other epiphytes. These types of plants are difficult to measure. Unless they form a significant component of the ecosystem, they should not be measured, which is conservative as their biomass is usually much reduced in the LU/LC classes adopted after deforestation.

Carbon stock estimations for the non-tree vegetation components are usually based on destructive harvesting, drying and weighting. These methods are described in the Sourcebook for LULUCF projects (Pearson *et al*., 2005) from which most of the following explanations are taken.

For herbaceous plants, a square frame of 1m^2 made from PVC pipe or another appropriated material is sufficient for sampling. For shrubs and other large non-tree vegetation, similar or larger frames should be used (about 1-2 m^2, depending on the size, distribution and frequency of this vegetation). For specific *forest* species (e.g. bamboo) or crop types (e.g. coffee) it is also possible to develop allometric equations. When using destructive sampling, apply the following steps:

a. Place the clip frame at the sampling site. If necessary, open the frame and place around the vegetation.

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[71]   Reyes *et al.*, 1992. Wood densities of tropical tree species. USDA

b. Clip all vegetation within the frame to ground level. Cut everything growing within the quadrate (ground surface not three-dimensional column) and sample this.

c. Weigh the sample and remove a well-mixed sub-sample for determination of dry-to-wet mass ratio. Weight the sub-sample in the field, then oven-dry to constant mass (usually at ~ 70 ^{o}C).

d. Calculate the dry mass of each sample. Where a sub-sample was taken for determination of moisture content use the following equation:

$$Dry\ mass = \left(\frac{subsample\ dry\ mass}{subsample\ fresh\ mass} \right) * fresh\ mass\ of\ whole\ sample \qquad (A3\text{-}23)$$

e. The *carbon stock* in the above-ground non-tree biomass per hectare is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average *carbon stock* per *LU/LC class*, average over all samples:

$$Cabnt_{cl} = \frac{\sum_{pl=1}^{PLcl} DM_{pl} * XF * CF_{pl} * 44/12}{PL_{cl}} \qquad (A3\text{-}24)$$

Where:

$Cabnt_{cl}$ = Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO$_2$-e ha^{-1}

DM_{pl} = Dry mass of sample *pl*; tonnes of d.m.

XF = Plot expansion factor = [10.000 / Plot Area (m^2)]; dimensionless

CF_{pl} = Carbon fraction of sample *pl*; tonnes C (tonne d. m.)$^{-1}$

44/12 = Ratio converting C to CO$_2$-e

pl = 1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless

PL_{cl} = Total number of plots in LU/LC class *cl*; dimensionless

f. The carbon stock per hectare of the below-ground non-tree biomass is calculated by multiplying the estimated above-ground estimate by and appropriate root to shoot ratio.

Estimation of carbon stocks in the dead wood carbon pool (Cdw_{cl})

Carbon stocks in the dead wood carbon pool can be significant in forest classes although is usually insignificant or zero in most agricultural and pastoral LU/LC classes. However, if burning is used to clear slash, dead wood maybe a significant component of carbon stocks in agricultural/pasture, especially in the short term. Therefore, in most cases it will be conservative to ignore the dead wood carbon pool.

Deadwood comprises two types: standing dead wood and lying dead wood. Different sampling and estimation procedures are used to estimate the carbon stocks of the two components.

$$Cdw_{cl} = Csdw_{cl} + Cldw_{cl} \qquad \text{(A3-25)}$$

Where:

Cdw_{cl} = Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class cl; tCO_2-e ha^{-1}

$Csdw_{cl}$ = Average carbon stock per hectare in the standing dead wood carbon pool of the LU/LC class cl; tCO_2-e ha^{-1}

$C\tilde{n}dw_{cl}$ = Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class cl; tCO_2-e ha^{-1}

Standing dead wood shall be measured using the sampling criteria and monitoring frequency used for measuring live trees. Lying deadwood shall be measured using the transect method as explained below. The description of the method to measure lying deadwood is taken from Harmon and Sexton (1996).

Standing dead wood ($Csdw_{cl}$)

a. Within the plots delineated for live trees, the diameter at breast height (*DBH*) of standing dead trees can also be measured. In addition, the standing dead wood is categorized under the following four decomposition classes:

    1. Tree with branches and twigs that resemble a live tree (except for leaves);

    2. Tree with no twig, but with persistent small and large branches;

    3. Tree with large branches only;

    4. Bole (trunk) only, no branches.

b. For classes 2, 3 and 4, the height of the tree (*H*) and the diameter at ground level should be measured and the diameter at the top should be estimated. Height can be measured using a clinometer.

c. Top diameter can be estimated using a relascope or through the use of a transparent measuring ruler. Hold the ruler approximately 10-20 cm from your eye and record the apparent diameter of the top of the tree. The true diameter is the equal to:

$$True \ \ diameter - (m) = \frac{Dis\tan ce \ eye \ to \ tree \ (m)}{Dis\tan ce \ eye \ to \ ruler \ (m)} * Ruler \ measurment \ (m) \quad \text{(A3-26)}$$

Distance can also be measured with a laser range finder.

d. For decomposition class 1 the carbon content of each dead tree is estimated using the allometric or *BEF* methods applied for live trees and by subtracting out the biomass of leaves (about 2-3% of the above-ground biomass for hardwood/broadleaf species and 5-6% for softwood/conifer species).

e. For classes 2, 3 and 4, where it is not clear what proportion of the original biomass has been lost, it is conservative to estimate the biomass of just the bole (trunk) of the tree.

The volume is calculated using *DBH* and height measurements and the estimate of the top diameter. It is then estimated as the volume of a truncated cone:

$$Volume \ (m3) = 1/3 * \pi * H * \left(r_1^2 + r_2^2 + r_1 * r_2 \right)$$ (A3-27)

Where:

H   =   Height of the tree; meters

r_1 =   Radius at the base of the tree; meters

r_2 =   Radius at the top of the tree; meters

The volume is converted to dry biomass using the appropriate wood density D_j and then to carbon dioxide equivalents using the carbon fraction Cu_{ff} and CO_2/C ratio (44/12), as in the *BEF* method, but ignoring the Biomass Expansion Factor.

f. To aggregate the carbon stock of each standing dead tree at the plot level and then at the LU/LC class level, continue with step a.4 of the allometric equation method.

Lying dead wood (*Cldw$_{cl}$*)

Lying dead wood is most efficiently measured using the line-intersect method. Only coarse dead wood above a predefined minimum diameter (e.g. > 10 cm) is measured with this method – dead wood with smaller diameter can be measured with litter.

a. At each plot location, lay out two lines of 50 meters either in a single line or at right angles. The lines should be outside the boundaries of the plot to avoid damage to seedlings in the plots during measurement, and also to biasing the dead wood pool by damaging during tree measurement. Alternatively, separate and independent sampling of lying deadwood may be used, in which case deadwood transects must be randomly located (to avoid subjective choice of plots locations), without sample replacement, using the same procedure used for live trees[72]. Their location must also be permanently marked and their coordinates reported.

b. Along the length of the lines, measure the diameter of each intersecting piece of coarse dead wood above a predefined minimum diameter (e.g. > 10 cm). Calipers work best for measuring the diameter. A piece of dead wood should only be measured if: (a) more than 50% of the log is above-ground and (b) the sampling line crosses through at least 50% of the diameter of the piece. If the log is hollow at the intersection point, measure the diameter of the hollow: the hollow portion in the volume estimates should be excluded.

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[72] Using this alternate approach, transects may be located in places distant to live trees plots, increasing sampling costs. Even if lying deadwood stocks are very homogeneous in all the strata, implying that fewer samples will be required, the cost of additional displacements and work won't probably compensate for the decrease in samples number.

c. Assign each piece of dead wood to one of the three following density classes:

    1. Sound

    2. Intermediate

    3. Rotten

    To determine what density class a piece of dead wood fits into, each piece should be struck with a machete. If the blade does not sink into the piece (that is, it bounces off), it is classified as sound. If it sinks partly into the piece and there has been some wood loss, it is classified as intermediate. If the blade sinks into the piece, there is more extensive wood loss and the piece is crumbly, it is classified as rotten.

d. At least 10 random dead wood samples of each three density classes, representing a range of species present, should be collected for density determination. This determination can be accomplished using the maximum moisture content method (Smith 1954), which does not require sample volume determination. Using a chainsaw or a handsaw, cut a compete disc or a piece of reasonable size from the selected piece of dead wood and bring to the laboratory for wood density determination.

e. Submerge wood samples in water until saturation is reached. Weight saturated samples. Then, dry samples at 105°C for 26 hours. Extract and weight samples again. Do this last weight quickly, withdrawing samples from oven immediately before weighting them, so that no moisture is absorbed by dried samples before obtaining weights.

f. Calculate the wood density for each density class (sound, intermediate, rotten) from the pieces of dead wood collected. Density is calculated by the following equation:

$$Dm = \frac{1}{\frac{ps - po}{po} + \frac{1}{1.53}} \qquad (A3\text{-}28)$$

Where:

Dm = Deadwood density; g cm^{-3}

Ps = Saturated weight of sample; g

Po = Anhydrous weight of sample, g

1.53   = Wood density constant

Average the densities to get a single density value for each class.

g. For each density class, the volume is calculated separately as follows:

$$Volume \ (m^3 / ha) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + ...d_n^2}{8 * L} \right) \qquad (A3\text{-}29)$$

Where:

$d_1, d_2, ..., d_n$ = Diameters of intersecting pieces of dead wood; cm

L =   Length of the line; meters

h.   The per hectare carbon stock in the lying dead wood carbon pool of each LU/LC class is calculated as follows:

$$Cldw_{cl} = \frac{\sum_{pl=1}^{PL_{cl}} \left(\sum_{dc=1}^{DC} Volume_{dc} * D_{dc} * CF_{dc} * 44/12 \right)_{pl}}{PL_{cl}} \qquad (A3\text{-}30)$$

Where:

$Cldw_{cl}$ =   Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class cl; tCO_2-e ha^{-1}

$Volume_{dc}$ =   Volume of laying dead wood in the density class dc; m^3

D_{dc} =   Dead wood density of class dc; tonnes d. m. m^{-3}

CF_{dc} =   Carbon fraction of the density class dc; tonnes C (tonne d. m.)$^{-1}$

44/12   =   Ratio converting C to CO_2-e

pl =   1, 2, 3, … PL_{cl} plots in LU/LC class cl; dimensionless

PL_{cl} =   Total number of plots in LU/LC class cl; dimensionless

dc =   1, 2, 3 dead wood density classes; dimensionless

DC =   Total number of density classes (3); dimensionless

Estimation of carbon stocks in the litter carbon pool (CL_{cl})

In some forest ecosystem litter carbon stocks in the litter carbon pool can be a significant component of the total carbon stock while in anthropogenic ecosystem, particularly in agricultural or pastoral systems, litter is almost absent.

Litter is defines as all dead organic surface material on top of the mineral soil not considered in the lying dead wood pool. Some of this material is recognizable (for example dead leaves, twigs, dead grasses and small branches) and some is unidentifiable (decomposed fragments of different components of originally live biomass. To differentiate small woody debris from the laying dead wood it is necessary to define a diameter (i.e. 10 cm) below which small dead wood pieces are classified as litter and above which they are considered dead wood.

If litter is measured, it should be sampled at the same time of the year at each monitoring event in order to eliminate seasonal effects. The sampling technique is similar to the one used for non-tree vegetation: a square frame of 1.0 m^2 made from PVC pipe or another suitable material can be used. The following description of the sampling and data analysis techniques is taken from the sourcebook for LULUCF projects (Pearson *et al.*, 2005).

a.   Place the sampling frame at the sample site.

b. Collect all the litter inside the frame. Pieces of twigs or wood that cross the border of the frame should be cut using a knife or pruning scissors. Place all the litter on a tarpaulin beside the frame or inside a weighting bag. Weigh the sample on-site, then oven-dry to a constant weight.

c. Where sample bulk is excessive, the fresh weight of the total sample should be recorded in the field and a sub-sample of manageable size (approximately 80-100 g) taken for moisture content determination, from which the total dry mass can be calculated.

d. Calculate the dry mass of the sample. Where a sub-sample was taken for determination of the moisture content use equation 30 to estimate the dry mass of the whole sample.

e. The carbon stock per hectare in the litter carbon pool is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average carbon stock per LU/LC class, average over all samples (see equation 31).

Estimation of carbon stocks in soil organic carbon pool ($Csoc_{cl}$)

Methods to estimate *carbon stocks* in the soil organic carbon pool are described in the sourcebook for LULUCF projects (Pearson *et al.*, 2006) from which the following explanations have been taken.

Three types of variables must be measured to estimate soil organic carbon stocks: (1) depth, (2) bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material), and (3) the concentrations of organic carbon within the sample.

The sample depth should be constant, 30 cm is usually a sufficient sampling depth.

a. Steadily insert the soil probe to a 30 cm depth. If the soil is compacted, use a rubber mallet to fully insert. If the probe will not penetrate to the full depth, do not force it as it is likely a stone or root that is blocking its route and, if forced, the probe will be damaged. Instead, withdraw the probe, clean out any collected soil and insert in a new location.

b. Carefully extract the probe and place the sample into a bag. Because the carbon concentration of organic materials is much higher than that of the mineral soil, including even a small amount of surface material can result in a serious overestimation of soil *carbon stocks*.

c. To reduce variability, aggregate four samples from each collection point for carbon concentration analysis.

d. At each sampling point, take two additional aggregated cores for determination of bulk density. When taking the cores for measurements of bulk density, care should be taken to avoid any excess or loss of soil from the cores.

e. Soil samples can be sent to a professional laboratory for analysis. Commercial laboratories exist throughout the world and routinely analyze plant and soil samples

using standard techniques. It is recommended the selected laboratory be checked to ensure they follow commonly accepted standard procedures with respect to sample preparation (for example, mixing and sieving), drying temperatures and carbon analysis methods.

For bulk density determination, ensure the laboratory dries the samples in an oven at 105 $^{\circ}$C for a minimum of 48 hours. If the soil contains coarse, rocky fragments, the coarse fragments must be retained and weighted. For soil carbon determination, the material is sieved through a 2 mm sieve, and then thoroughly mixed. The well-mixed sample should not be oven-dried for the carbon analysis, but only air-dried; however, the carbon concentration does need to be expressed on an oven dry basis at 105 $^{\circ}$C. The dry combustions method using o controlled temperature furnace (for example, a LECO CHN-2000 or equivalent) is the recommended method for determining total soil carbon, but the Walkley-Black method is also commonly used.

f. Calculate the bulk density of the mineral soil core:

$$Bulk\ density\ (g/cm^3) = \frac{oven\ dry\ mass\ (g/cm^3)}{core\ volume\ (cm^3) - \dfrac{mass\ of\ coarse\ fragments\ (cg)}{density\ of\ rock\ fragments\ (cg/m^3)}} \quad \text{(A3-31)}$$

Where the bulk density is for the < 2 mm fraction, coarse fragments are > 2 mm. The density of rock fragments is often given as 2.65 g/cm^3.

g. Using the carbon concentration data obtained from the laboratory, the amount of carbon per unit area is given by:

$$Csoc_{cl}\ (t/ha) = [(soil\ bulk\ density\ (g/cm^3) * soil\ depth\ (cm) * C)] * 100 \quad \text{(A3-32)}$$

In the above equation, C must be expressed as a decimal fraction. For example, 2.2% carbon is expressed as 0.022 in the equation.

h. The *carbon stock* per hectare in the soil organic carbon pool is calculated by averaging the *carbon stock* estimates per each *LU/LC class*:

$$Csoc_{cl} = \frac{\displaystyle\sum_{pl=1}^{PL_{pl}} Csoc_{pl}}{PL_{pl}} \quad \text{(A3-33)}$$

Where:

$Csoc_{cl}$ = Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class *cl*; tCO$_2$-e ha^{-1}

$Csoc_{pl}$ = **Carbon stock** per hectare in the soil organic carbon pool estimated for the plot *pl*; tCO$_2$-e ha^{-1}

pl = 1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless

PL_{pl} = Total number of plots in LU/LC class *cl*; dimensionless

Estimation of *carbon stocks* in the harvested wood products carbon pool (*Cwp_{cl}*)

The wood products carbon pool must be included if there is timber harvest in the baseline case prior to or in the process of deforestation and the wood products carbon pool is determined to be significant. In this case, *Cwp_{cl}* must be subtracted in the calculation of *Ctot_{cl}* in the baseline case and can be added in the calculation of *Ctot_{cl}* in the project case.

Carbon stocks in wood products are those stocks remaining in wood products after 100 years; the bulk of emissions associated with timber harvest, processing and waste, and eventual product retirement occur within this timeframe, and calculations employ the simplifying assumption that the proportion remaining after 100 years is effectively "permanent."

Accounting for carbon stocks in wood products in the baseline case should only take place at the time of deforestation (year *t*). In the project case, *Cwp_{cl}* can be accounted at the years of planned timber harvest, in which case monitoring is mandatory.

This module follows the conceptual framework detailed in Winjum *et al.* 1998[73], applying the simplifying (and conservative) assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al.* 1998.

If approved timber harvest plans, specifying harvest intensity per forest class in terms of volume extracted per ha, are available for the Project area use Method 1. If approved harvest plans are not available use Method 2.

Method 1: Direct Volume Extraction Estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted since the project start date and in the process of deforestation as follows:

$$CXB_{w,fcl,t} = \frac{1}{ABSLPA_{fcl,t}} * (\sum_{t=1}^{t^*} \sum_{j=1}^{J} (VEX_{w,j,fcl,t} * D_j * CF_j * \frac{44}{12})) \qquad \text{(A3-34)}$$

Where:

$CXB_{w,fcl,t}$ = Mean carbon stock per hectare of extracted biomass carbon by class of wood product *w* from forest class *fcl* at time *t*; tCO_2-e ha^{-1}

fcl = 1, 2, 3, …*Fcl* pre-deforestation forest classes; dimensionless

w = 1, 2, 3 ... *W* Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless

t = 1, 2, 3… *T* years, a year of the project crediting period; dimensionless

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[73] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

$t*$ = the year at which the area A$BSLPA_{fcl,t}$ is deforested in the baseline case; dimensionless

j = 1, 2, 3 ... J tree species; dimensionless

$ABSLPA_{fcl,t}$ = Area of forest class fcl deforested at year $t*$; ha

$VEX_{,w,j,fcl,t}$ = Volume of timber for product class w, of species j, extracted from within forest class fcl at time t; m^3

D_j = Mean wood density of species j; t d.m.m^{-3}

CF_j = Carbon fraction of biomass for tree species j; t C t^{-1}d.m.

$44/12$ = Ratio of molecular weight of CO$_2$ to carbon; dimensionless

Step 2: Calculate the proportion of biomass carbon extracted at time t that remains sequestered in long-term wood products after 100 years.

$$Cwp_{fcl,t} = \sum_{w=1}^{W} CXB_{w,fcl,t} * (1 - WW_w) * (1 - SLF_w) * (1 - OF_w) \qquad \text{(A3-35)}$$

Where:

$Cwp_{fcl,t}$ = Carbon stock in the wood products carbon pool (stock remaining in wood products after 100 years) in forest class fcl at time t; tCO$_2$-e ha^{-1}

fcl = 1, 2, 3, …Fcl forest classes; dimensionless

w = 1, 2, 3 ... W Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless

t = 1, 2, 3… T years, a year of the project crediting period; dimensionless

$CXB_{w,fcl,t}$ = Mean stock of extracted biomass carbon by class of wood product w from forest class fcl at time t; tCO$_2$-e ha^{-1}

WW_w = Wood waste for wood product class w. The fraction immediately emitted through mill inefficiency; dimensionless

SLF_w = Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless

OF_w = Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless

Method 2: Commercial inventory estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of deforestation:

$$CXB_{fcl,t} = Cab_{ifcl,t} * \frac{1}{BCEF} * Pcom_{fcl} \qquad\qquad (A3\text{-}36)$$

Where:

$CXB_{fcl,t}$ =   Mean stock of extracted biomass carbon from forest class *fcl* at time *t*; tCO$_2$-e ha^{-1}

$Cab_{fcl,t}$ =   Mean above-ground biomass carbon stock in forest class *fcl* at time *t*; tCO$_2$-e ha^{-1}

$BCEF$ =   Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass; dimensionless

$Pcom_{fcl}$ =   Commercial volume as a percent of total aboveground volume in *forest class fcl*; dimensionless

t =   1, 2, 3… *T* years, a year of the project crediting period; dimensionless

fcl =   1, 2, 3, …*Fcl* forest classes; dimensionless

Step 2: Identify the wood product class(es) (*w*, defined here as sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in step 1. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

Step 3: Calculate the proportion of biomass carbon extracted at time *t* that remains sequestered in long-term wood products after 100 years. This module applies the simplifying (and conservative) assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al.* 1998.

$$Cwp_{fcl,t} = \sum_{w=1}^{W} CXB_{w,fcl,t} * (1 - WW_w) * (1 - SLF_w) * (1 - OF_w) \qquad (A3\text{-}37)$$

Where:

$Cwp_{fcl,t}$ =   Carbon stock in wood products pool (stock remaining in wood products after 100 years) in forest class *fcl* at time *t*; tCO$_2$-e ha^{-1}

fcl =   1, 2, 3, …*Fcl* forest classes; dimensionless

w =   Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless

t =   1, 2, 3 … *T* years, a year of the project crediting period; dimensionless

$CXB_{w,fcl,t}$ = Mean stock of extracted biomass carbon by class of wood product w from forest class fcl at time t; tCO_2-e ha^{-1}

WW_w = Wood waste for wood product class w. The fraction immediately emitted through mill inefficiency; dimensionless

SLF_w = Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless

OF_w = Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless

APPENDIX 4:
Methods to estimate emissions from enteric fermentation and manure management

Estimation of CH$_4$ emissions from enteric fermentation (*ECH4ferm$_{,t,t}$*)

The amount of methane[74] emitted by a population of animals is calculated by multiplying the emission rate per animal by the number of animals above the baseline case. To reflect the variation in emission rates among animal types, the population of animals is divided into subgroups, and an *emission factor* per animal is estimated for each subgroup. As per IPCC GPG 2000 and IPCC 2006 Guidelines for AFOLU, use the following equation[75]:

$$ECH4\,ferm_t = EF_1 * Population_t * 0,001 * GWP_{CH4} \qquad \text{(A4-1)}$$

$$Population_t = Pforage_t / (DBI * 365) \qquad \text{(A4-2)}$$

Where:

ECH4ferm$_t$	=	CH$_4$ emissions from enteric fermentation at year *t*; tCO$_2$e
EF$_1$	=	Enteric CH$_4$ emission factor for the livestock group; kg CH$_4$ head^{-1} yr^{-1}
Population$_t$	=	Equivalent number of forage-fed livestock at year *t*; heads
Pforage$_t$	=	Production of forage at year *t*; kg d.m. yr^{-1}
DBI	=	Daily biomass intake; kg d.m. head^{-1} day^{-1}
GWP$_{CH4}$	=	Global warming potential for CH$_4$ (with a value of 21 for the first commitment period); dimensionless
0.001	=	Conversion factor of kilograms into tonnes; dimensionless
365	=	Number of day per year; dimensionless
t	=	1, 2, 3, ... *T* years of the project crediting period

The production of forage can be estimated by collecting production rates from the literature that represents the shrub species, climate, soil conditions and other features of the areas in which forage will be produced. Sampling surveys is also a good option.

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[74] Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce CH$_4$, although ruminants are the largest source since they are able to digest cellulose, due to the presence of specific micro organisms in their digestive tracts. The amount of CH$_4$ that is released depends on the type, age, and weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal.

[75] Refer to equation 10.19 and equation 10.20 in IPCC 2006 GL AFOLU or equation 4.12 and equation 4.13 in GPG 2000 for agriculture.

Country-specific emission factors for enteric CH_4 emissions are documented in peer reviewed literature or can be obtained from national GHG inventories. Default values are given in table 10.10 and 10.11 in the IPCC 2006 Guidelines for AFOLU. When selecting emission factors it is important to select those from a region that is similar to the Project area. The tables in Annex 10A.1 of the IPCC 2006 Guidelines for AFOLU specify the animal characteristic such as weight, growth rate and milk production used to estimate the emission factors. These tables should be consulted in order to ensure that the local conditions are similar. In particular, data on average milk production by dairy livestock should be analyzed when selecting an emission factor for dairy livestock. To estimate the emission factor, the data in table 10A.1 can interpolated using the data on the local average milk production.

For data on daily biomass intake use local data or data that are applicable to the local conditions according to peer-reviewed literature or the national GHG inventory. When selecting a value for daily biomass intake, ensure that the chosen data are applicable to both the forage types to be produced and the livestock group (see also table 5 in appendix 2).

Estimation of CH_4 emissions from manure management ($ECH4man_t$) [76]

The storage and treatment of manure under anaerobic conditions produces CH_4. These conditions occur most readily when large numbers of animals are managed in confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid based systems. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of manure that decomposes anaerobicly. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobicly and can produce a significant quantity of CH_4. The temperature and the retention time of storage greatly affect the amount on methane produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.

CH_4 emissions from manure management for the forage-fed livestock can be estimated using IPCC methods[77].

$$ECH4man_t = EF_2 * Population_t * 0,001 * GWP_{CH4} \qquad \text{(A4-3)}$$

Where:

$ECH4man_{t,t}$ = CH_4 emissions from manure management at year t; tCO_2e

EF_2 =   Manure management CH_4 emission factor for the livestock group; kg CH_4 head^{-1} yr^{-1}

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[76]   Taken from AR-AM0006 version 1

[77]   Refer to equation 10.22 in AFOLU volume of the IPCC 2066 Guidelines or equation 4.15 in GPG 2000 for agriculture.

$Population_t$	=	Equivalent number of forage-fed livestock at year t; heads
GWP_{CH4}	=	Global warming potential for CH_4 (with a value of 21 for the first commitment period); dimensionless
0.001	=	Conversion factor of kilograms into tonnes; dimensionless
t	=	1, 2, 3, … T years of the project crediting period

The best estimate of emissions will usually be obtained using country-specific emission factors that have been published in peer-reviewed literature or in the national GHG inventory. It is recommended that country-specific emission factors be used that reflect the actual duration of storage and type of treatment of animal manure in the management system used. If appropriate country-specific emission factors are unavailable, default emission factors presented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU may be used. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project area.

Estimation of N$_2$O emissions from manure management (*EN2Oman$_t$*) [78]

Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. The N$_2$O emissions from manure management can be estimated using method provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000 [79]

$$EN2Oman_t = EdirN2Oman_t + EindN2Oman_t \qquad \text{(A4-4)}$$

$$EdirN2Oman_t = Population_t * Nex * EF_3 \cdot 0{,}001 * 44/28 * GWP_{N20} \qquad \text{(A4-5)}$$

$$EindN2Oman_t = Population_t * Nex * Frac_{gas} * EF_4 * 0{,}001 * 44/28 * GWP_{N2O} \qquad \text{(A4-6)}$$

Where:

$EN2Oman_{fcl,t}$	=	N$_2$O emissions from manure management at year t; tCO$_2$e[1]
$EdirN_2Oman_t$	=	Direct N$_2$O emissions from manure management at year t; tCO$_2$e

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[78] Taken from AR-AM0006 version 1

[79] Refer to equations 10.25, 10.26 and 10.27 in AFOLU volume of the IPCC 2006 Guidelines and/or equation 4.18 in GPG 2000 for agriculture.

EindNOman$_t$	=	Indirect N$_2$O emissions from manure management at year *t*; tCO$_2$e
Population$_t$	=	Equivalent number of forage-fed livestock at year *t*; heads
Nex	=	Annual average N excretion per livestock head; kg N head^{-1} yr^{-1}
EF$_3$	=	Emission factor for N$_2$O emissions from manure management for the livestock group; kg N$_2$O-N (kg N^{-1}) head^{-1} yr^{-1}
EF$_4$	=	Emission factor for N$_2$O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces; kg N$_2$O-N (kg NH$_3$-N and NO$_x$-N emitted)$^{-1}$ head^{-1} yr^{-1}

Note: The use of the IPCC default factor 0.01 is recommended.

Frac$_{gas}$	=	Fraction of managed livestock manure nitrogen that volatilizes as NH3 and NOx in the manure management phase; kg NH$_3$-N and NO$_x$-N emitted (Kg N)$^{-1}$
GWP$_{N2O}$	=	Global warming potential for N$_2$O (310 for the first commitment period); dimensionless
44/28	=	Conversion of N$_2$0-N emissions to N$_2$O emissions
0.001	=	Conversion factor of kilograms into tonnes; dimensionless

The best estimate of the annual nitrogen excretion rates for each livestock group will usually be obtained using country-specific rates from published peer reviewed literature or from the national GHG inventory. If country-specific data cannot be collected or derived, or appropriate data are not available from another country with similar conditions, default nitrogen excretion rates can be obtained from table 10.19 of IPCC 2006 Guidelines for AFOLU.

The possible data sources for emission factors are similar. Default emission factors are given in table 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU and default values for volatilization of NH$_3$ and NO$_x$ (*Frac$_{gas}$*) in the manure management system are presented in table 10.22 of the same IPCC 2006 Guidelines. For *EF$_4$* the IPCC default value 0.01 is recommended (equation 10.27, IPCC 2006 Guidelines for AFOLU).

APPENDIX 5:
Data and parameters used in this methodology

Notation	Description	Unit	Equation	Observation	Source	Monitoring
A	Area of error due to observed change predicted as persistence	ha	13		calcuated	each renewal of fixed baseline period
$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum	ha	5.b, 6.b, 10		calculated	each renewal of fixed baseline period
$Aaverage_{i,t1}$	Area with forest cover in stratum i on "average" areas at time $t1$	ha	6.b		calculated	each renewal of fixed baseline period
$Aaverage_{i,t2}$	Area with forest cover in stratum i on "average" areas at time $t2$	ha	6.b		calculated	each renewal of fixed baseline period
$ABSLL_{fcl,t}$	Area of final (post-deforestation) non-forest class fcl deforested at time t within the leakage belt in the baseline case	ha	14		calculated	each renewal of fixed baseline period
$ABSLLK_{ct,t}$	Area of category ct deforested at time t within the leakage belt in the baseline case	ha	15		measured or estimated from literature	each renewal of fixed baseline period
$ABSLLK_{i,t}$	Annual area of baseline deforestation in stratum i within the leakage belt at year t;	ha	11		calculated	each renewal of fixed baseline period
$ABSLLK_{icl,t}$	Area of initial (pre-deforestation) forest class icl deforested at time t within the leakage belt in the baseline case	ha	14		calculated	each renewal of fixed baseline period

$ABSLPA_{ct,t}$	Area of category ct deforested at time t within the project area in the baseline case	ha	15		measured or estimated from literature	each renewal of fixed baseline period
$ABSLPA_{fcl,t}$	Area of final (post-deforestation) non-forest class fcl deforested at time t within the project area in the baseline case	ha	14		calculated	each renewal of fixed baseline period
$ABSLPA_{i,t}$	Annual area of baseline deforestation in stratum i within the project area at year t;	ha	12		calculated	each renewal of fixed baseline period
$ABSLP_{icl,t}$	Area of initial (pre-deforestation) forest class icl deforested at time t within the project area in the baseline case	ha	14		calculated	each renewal of fixed baseline period
$ABSLRRopt\_hrp_i$	Average area deforested in $Aaverage_i$ during the historical reference period	ha	5.a		calculated	each renewal of fixed baseline period
$ABSLRR_{ct,t}$	Area of category ct deforested at time t within the reference region in the baseline case	ha	15		measured or estimated from literature	each renewal of fixed baseline period
$ABSLRR_{fcl,t}$	Area of final (post-deforestation) non-forest class fcl deforested at time t within the reference region in the baseline case	ha	14		calculated	each renewal of fixed baseline period
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum i within the reference region at year t	ha	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		calculated	each renewal of fixed baseline period
$ABSLRR_{i,taverage}$	Annual area of baseline deforestation in stratum i within the Reference region at a year $taverage_i$	ha	11		calculated	each renewal of Fixed Baseline Period
$ABSLRR_{icl,t}$	Area of initial (pre-deforestation) forest class icl deforested at time t within the reference region in the baseline case	ha	14		calculated	each renewal of fixed baseline period

$ABSLRRopt\_hrp_i$	Average area deforested in $Aoptimal_i$ during the historical reference period	ha	5.b		calculated	each renewal of fixed baseline period
$ABSLRRsopt\_hrp_i$	Average area deforested in $Asub\text{-}optimal_i$ during the historical reference period	ha	5.c		calculated	each renewal of fixed baseline period
$ABSLRR_{i,taverage}$	Annual area of baseline deforestation in stratum i within the Reference Region at a year $taverage_i$	ha yr^{-1}	11		calculated	each renewal of fixed baseline period
$Aoptimal_i$	Area of "optimal" forest land suitable for conversion to non-forest land within stratum i	ha	3, 7		calculated	each renewal of fixed baseline period
$Aoptimal_{i,t1}$	Area with forest cover in stratum i on "optimal areas at time $t1$	ha	6.a		calculated	each renewal of fixed baseline period
$Aoptimal_{i,t2}$	Area with forest cover in stratum i on "optimal areas at time $t2$	ha	6.a		calculated	each renewal of fixed baseline period
AP	Plot area	m^2	A3-13		measured or estimated from literature	only once at project start and when mandatory
$APDPA_{icl,t}$	Areas of planned deforestation in forest class icl at year t in the project area	ha		*ex ante* and *ex post*	measured or estimated from literature	annually
$APF_{icl,t}$	Annual area of planned fuel-wood and charcoal activities in forest class icl at year t in the project area	ha		*ex ante* and *ex post*	calculated *ex ante*, measured *ex post*	annually
$APLPA_{icl,t}$	Areas of planned logging activities in forest class icl at year t in the project area	ha		*ex ante* and *ex post*	calculated ex *ante*, measured *ex post*	annually
$APNiPA_{icl,t}$	Annual area of forest class icl with increasing carbon stock without harvest at year t in the project area	ha		*ex ante* and *ex post*	calculated ex *ante*, measured *ex post*	annually

$ARRaverage_{i,t1}$	Area with forest cover in stratum i on average and sub-optimal areas at time $t1$	ha	4.b		calculated	each renewal of fixed baseline period
$ARRaverage_{i,t2}$	Area with forest cover in stratum i on average and sub-optimal areas at time $t2$	ha	4.b		calculated	each renewal of fixed baseline period
ARR_i	Total forest area in stratum i within the reference region at the project start date	ha	6, 11		measured or estimated from literature	each renewal of fixed baseline period
$ARR_{i,t-1}$	Area with forest cover in stratum i within the reference region a year $t-1$	ha	3		calculated	each renewal of fixed baseline period
$ARRoptimal_{i,t1}$	Area with forest cover in stratum i on optimal areas at time $t1$	ha	4.a		calculated	each renewal of fixed baseline period
$ARRoptimal_{i,t2}$	Area with forest cover in stratum i on optimal areas at time $t2$	ha	4.a		calculated	each renewal of fixed baseline period
$ARRsub\_optimal_{i,t1}$	Area with forest cover in stratum i on sub-optimal areas at time $t1$	ha	4.c		calculated	each renewal of fixed baseline period
$ARRsub\_optimal_{i,t2}$	Area with forest cover in stratum i on sub-optimal areas at time $t2$	ha	4.c		calculated	each renewal of fixed baseline period
$Asub\text{-}optimal_{i,t1}$	Area with forest cover in stratum i on "sub-optimal" areas at time $t1$	ha	6.c		calculated	each renewal of fixed baseline period
$Asub\text{-}optimal_{i,t2}$	Area with forest cover in stratum i on "sub-optimal" areas at time $t2$	ha	6.c		calculated	each renewal of fixed baseline period
B	Area correct due to observed change predicted as change	ha	13		measured or estimated from literature	each renewal of fixed baseline period

$BCEF$	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass	dimensionless	A3-9, A3-36		measured or estimated from literature	only once at project start
$BEFpl$	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree tr, in plot pl	dimensionless	A3-21		measured or estimated from literature	only once at project start
Cab_{cl}	Average carbon stock per hectare in the above-ground biomass carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-6, A3-14, A3-36		measured or estimated from literature	only once at project start and when mandatory
$Cabnt_{cl}$	Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-7, A3-24		measured or estimated from literature	only once at project start and when mandatory
$Cabt_{cl}$	Average carbon stock per hectare in the above-ground tree biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-7		measured or estimated from literature	only once at project start and when mandatory
Cbb_{cl}	Average carbon stock per hectare below-ground biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-6, A3-17		measured or estimated from literature	only once at project start and when mandatory
$Cbbnt_{cl}$	Average carbon stock per hectare below-ground non-tree biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
$Cbbt_{cl}$	Average carbon stock per hectare below-ground tree biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
Cdw_{cl}	Average carbon stock per hectare in the in the dead wood biomass carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-6, A3-25		measured or estimated from literature	only once at project start and when mandatory
$CE_{p,icl}$	Average combustion efficiency of the carbon pool p in the forest class	dimensionless	19		measured or estimated from literature	only once at project start

CF_{dc}	Carbon fraction of the density class dc	tonnes C (tonne d. m.)$^{-1}$	A3-30		measured or estimated from literature	only once at project start and when mandatory
CF_j	Carbon fraction for tree tr, of species, group of species or forest type j	tonnes C (tonne d. m.)$^{-1}$	A3-11, A3-21, A3-24		measured or estimated from literature	only once at project start
CF_{pl}	Carbon fraction of sample pl	tonnes C (tonne d. m.)$^{-1}$	A3-24		calculated	only once at project start and when mandatory
cl	1, 2, 3 … Cl LU/LC classes	dimensionless	A3-3		measured or estimated from literature	each renewal of fixed baseline period
Cl_{cl}	Average carbon stock per hectare in the litter carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-6		measured or estimated from literature	only once at project start and when mandatory
$Cldw_{cl}$	Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class cl	t CO_2-e	A3-25, A3-30		measured or estimated from literature	only once at project start and when mandatory
$C_{p,icl,t}$	Average carbon stock per hectare in the carbon pool p burnt at year t in the forest class icl;	t CO_2-e ha^{-1}	19		calculated	only once at project start
$Csdw_{cl}$	Average carbon stock per hectare in the standing dead wood carbon pool of the LU/LC class cl	t CO_2-e ha^{-1}	A3-25		measured or estimated from literature	only once at project start and when mandatory
$Csoc_{cl}$	Average carbon stock per hectare in the soil organic carbon pool of LU/LC class cl	t CO_2-e ha^{-1}	A3-6, A3-33		measured or estimated from literature	only once at project start and when mandatory
$Csoc_pl$	Carbon stock per hectare in the soil organic carbon pool estimated for the plot pl;	t CO_2-e ha^{-1}	A3-33		measured or estimated from literature	only once at project start
ct	1, 2, 3 … CT categories of LU/LC change	dimensionless	15		calculated	each renewal of fixed baseline period

$Ctot_{cl}$	Average carbon stock per hectare in all accounted carbon pools of LU/LC class cl	t CO_2-e ha^{-1}	A3-6		calculated	only once at project start and when mandatory
$Ctot_{icl,t}$	Average carbon stock of all accounted carbon pools in forest class icl at time t	t CO_2-e ha^{-1}	14		calculated	only once at project start and when mandatory
Cwp_{cl}	Average carbon stock per hectare in the harvested wood products carbon pool (stock remaining in wood products after 100 years) of LU/LC class cl	t CO_2-e ha^{-1}	A3-6, A3-35, A3-37		measured or estimated from literature	only once at project start and when mandatory
$CXB_{w,icl,t}$	Mean carbon stock per hectare of extracted biomass carbon by class of wood product w from forest class icl at time t	t CO_2-e ha^{-1}	A3-35, A3-35, A3-37		measured or estimated from literature	only once at project start and when mandatory
$d1, d2, ..., dn$	Diameters of intersecting pieces of dead wood	cm	A3-29		measured or estimated from literature	only once at project start and when mandatory
DBH	Diameter at Breast Height	cm			measured or estimated from literature	only once at project start and when mandatory
DBI	Daily biomass intake	kg d.m. head^{-1} day^{-1}	A4-2		measured or estimated from literature	each renewal of fixed baseline period
dc	1, 2, 3 dead wood density classes	dimensionless	A3-30		defined	
DC	Total number of density classes (3)	dimensionless	A3-30		defined	
ΔCab_{ct}	Average carbon stock change factor in the below-ground biomass carbon pool of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
ΔCbb_{ct}	Average carbon stock change factor in the below-ground biomass carbon pool of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory

$\Delta CBSLPAf_t$	Total baseline carbon stock change in final classes within the project area at year t	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPAi_t$	Total baseline carbon stock change in initial forest classes within the project area at year t	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPA_t$	Total baseline carbon stock change within the project area at year t	t CO_2-e	14, 25		calculated	each renewal of fixed baseline period
ΔCdw_{ct}	Average carbon stock change factor in the dead wood biomass carbon pool of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CFCdPA_t$	Total decrease in carbon stock due to forest fires and catastrophic events at year t in the project area	t CO_2-e		*ex post*	calculated	annually
$\Delta CFCiPA_t$	Total increase in carbon stock due to forest fires and catastrophic events at year t in the project area	t CO_2-e		*ex post*	calculated	annually
ΔCl_{ct}	Average carbon stock change factor in the litter carbon pool of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
ΔCLK_t	Total decrease in carbon stocks within the leakage belt at year t	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CPAdPA_t$	Total decrease in carbon stock due to all planned activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPAiPA_t$	Total increase in carbon stock due to all planned activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPDdPA_t$	Total decrease in carbon stock due to planned deforestation at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually

$\Delta CPFdPA_t$	Total decrease in carbon stock due to planned fuel-wood and charcoal activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPFiPA_t$	Total increase in carbon stock due to planned fuel-wood and charcoal activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPLdPA_t$	Total decrease in carbon stock due to planned logging activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPLiPA_t$	Total increase in carbon stock due to planned logging activities at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPNiPA_t$	Total increase in carbon stock due to planned protection of growing forest classes in the project area at year t	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPSPA_t$	Total project carbon stock change within the project area at year t	t CO_2-e	25	*ex ante* and *ex post*	calculated	annually
$\Delta Csoc_{ct}$	Average carbon stock change factor in the soil organic carbon pool of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta Ctot_{ct,t}$	Carbon stock change factor (also called emission factor) for all accounted carbon pools in category ct at time t	t CO_2-e ha^{-1}	15		calculated	only once at project start and when mandatory
$\Delta Ctot_{ct}$	Average carbon stock change factor in all accounted carbon pools of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CUCdPA_t$	Total decrease in carbon stock due to catastrophic events at year t in the project area	t CO_2-e		*ex post*	calculated	annually

$\Delta CUCiPA_t$	Total increase in carbon stock in areas affected by catastrophic events (after such events) at year **t** in the project area	t CO_2-e		*ex post*	calculated	annually
$\Delta CUDdPA_t$	Total actual carbon stock change due to unavoided unplanned deforestation at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CUFdPA_t$	Total decrease in carbon stock due to unplanned (and planned – where applicable) forest fires at year t in the project area	t CO_2-e		*ex post*	calculated	annually
$\Delta CUFiPA_t$	Total increase in carbon stock in areas affected by forest fires (after such events) at year t in the project area	t CO_2-e		*ex post*	calculated	annually
ΔCwp_{ct}	Average carbon stock change factor in the harvested wood products carbon pool (stock remaining in wood products after 100 years) of category ct	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta REDD_t$	Net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year t	t CO_2-e	(25)	*ex ante* and *ex post*	calculated	annually
D_{dc}	Dead wood density of class dc	tonnes d. m. m^{-3}	A3-30		measured or estimated from literature	only once at project start and when mandatory
D_j	Mean wood density of species j	t d.m.m^{-3}	A3-34		measured or estimated from literature	only once at project start
DLF	Displacement Leakage Factor	%			defined	each renewal of fixed baseline period

Dm	Deadwood density	g cm-3	A3-28		measured or estimated from literature	only once at project start and when mandatory
DM_{pl}	Dry mass of sample $_{pl}$;	tonnes of d.m.	A3-24		measured or estimated from literature	only once at project start and when mandatory
$EBBBSLPA_t$	Sum of (or total) baseline non-CO_2 emissions from forest fire at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$EBBCH4_{icl}$	CH_4 emission from biomass burning in forest class icl	t CO_2-e	16, 18	*ex ante* and *ex post*	calculated	annually
$EBBCO2_{icl}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class icl	t CO_2-e ha^{-1}	17, 18, 19		calculated	only once at project start
$EBBN2O_{icl}$	N_2O emission from biomass burning in forest class icl	t CO_2-e	16, 17	*ex ante* and *ex post*	calculated	annually
$EBBPSPA_t$	Sum of (or total) actual non-CO_2 emissions from forest fire at year t in the project area	t CO_2-e		*ex ante* and *ex post*	calculated	annually
$EBBtot_{icl}$	Total GHG emission from biomass burning in forest class icl	t CO_2-e	16	*ex ante* and *ex post*	calculated	annually
$ECH4ferm_t$	CH_4 emissions from enteric fermentation at year t	t CO_2-e	A4-1		calculated	annually
$ECH4man_t$	CH_4 emissions from manure management at year t	t CO_2-e	A4-3		calculated	annually
$EdirN2Oman_t$	Direct N_2O emissions from manure management at year t	t CO_2-e	A4-4, A4-5		calculated	annually
$EF1$	Enteric CH_4 emission factor for the livestock group	kg CH_4 head^{-1} yr^{-1}	A4-1		calculated	each renewal of fixed baseline period
$EF1$	Emission Factor for emissions from N inputs	tN_2O tN^{-1}			measured or estimated from literature	each renewal of fixed baseline period

EF2	Manure management CH_4 emission factor for the livestock group	kg CH_4 head^{-1} yr^{-1}	A4-3		measured or estimated from literature	each renewal of fixed baseline period
EF3	Emission factor for N_2O emissions from manure management for the livestock group	kg N_2O-N (kg N^{-1}) head^{-1} yr^{-1}	A4-5		measured or estimated from literature	each renewal of fixed baseline period
EF4	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces	kg N_2O-N (kg NH_3-N and NO_x-N emitted)-1 head^{-1} yr^{-1}	A4-6		measured or estimated from literature	each renewal of fixed baseline period
EgLK$_t$	Emissions from grazing animals in leakage management areas at year *t*	t CO_2-e	23		calculated	annually
EI	Ex ante estimated Effectiveness Index	%			defined	annually
EindNOman$_t$	Indirect N_2O emissions from manure management at year *t*	t CO_2-e	A4-4, A4-5		calculated	annually
ELK$_t$	Sum of *ex ante* estimated leakage emissions at year *t*	t CO_2-e	23		calculated	annually
EN2Oman$_t$	N_2O emissions from manure management at year *t*	t CO_2-e	A4-4		calculated	annually
EN2Oman$_t$	N_2O emissions from manure management at year *t*	t CO_2-e	A4-4		calculated	annually
ERCH4	Emission ratio for CH_4 (IPCC default value = 0.012)	dimensionless	18		defined	each renewal of fixed baseline period
ERN2O	Emission ratio for N2O (IPCC default value = 0.007)	dimensionless	17		defined	each renewal of fixed baseline period
Fburnt$_{icl}$	Proportion of forest area burned during the historical reference period in the forest class *icl*	%	19		measured or estimated from literature	only once at project start
fcl	1, 2, 3 … *Fcl* final (post-deforestation) non-forest classes	dimensionless	14		measured or estimated from literature	each renewal of fixed baseline period

$f_j(DBH,H)_{ab}$	an allometric equation for species, or group of species, or forest type j, linking above-ground tree biomass (in kg tree^{-1}) to diameter at breast height (*DBH*) and possibly tree height (*H*).		A3-10		measured or estimated from literature	only once at project start
FOM	"Figure of Merit"	dimensionless	13	This is measure of goodness of fit between observed and predicted deforestation	calculated	each renewal of fixed baseline period
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period)	dimensionless	18		defined	each renewal of fixed baseline period
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)	dimensionless	17		defined	each renewal of fixed baseline period
H	Height of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
i	1, 2, 3 .. I_{RR} A stratum within the reference region	dimensionless	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		defined	each renewal of fixed baseline period
icl	1, 2, 3 … *Icl* initial (pre-deforestation) forest classes	dimensionless	14		measured or estimated from literature	each renewal of fixed baseline period
j	number of organic fertilizer types	dimensionless			defined	annually
L	Length of the line	m	A3-29		measured or estimated from literature	only once at project start and when mandatory
NCR	Nitrogen/Carbon ratio (IPCC default value = 0.01)	dimensionless	17		defined	each renewal of fixed baseline period

Nex	Annual average N excretion per livestock head	kg N head^{-1} yr^{-1}	A4-6		measured or estimated from literature	each renewal of fixed baseline period
OFw	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
p	Carbon pool that could burn (above-ground biomass, dead wood, litter)	dimensionless	19		defined	each renewal of fixed baseline period
Pburnt$_{p,icl}$	Average proportion of mass burnt in the carbon pool *p* in the forest class *icl*;	%	19		measured or estimated from literature	only once at project start
PCab$_{pl}$	Carbon stock in above-ground biomass in plot *pl*	tC ha^{-1}	A3-13		calculated	only once at project start and when mandatory
PCbb$_{pl}$	Carbon stock in below-ground biomass in plot *pl*	tC ha^{-1}	A3-16		calculated	only once at project start and when mandatory
Pcom$_{icl}$	Commercial volume as a percent of total aboveground volume in initial forest class *icl*	dimensionless	A3-36		measured or estimated from literature	only once at project start and when mandatory
PCx$_i$	Average in situ production costs for one ton of product *Px* in stratum *i*	$/t	1	This variable may have different values within different strata of the reference region	measured or estimated from literature	each renewal of fixed baseline period
Pforage$_t$	Production of forage at year *t*	kg d. m. yr^{-1}	A4-2		calculated *ex ante*, measured *ex post*	each renewal of fixed baseline period
pl	1, 2, 3, … *PLcl* plots in LU/LC class *cl*	dimensionless	A3-14, A3-17, A3-24, A3-33		calculated	only once at project start and when mandatory

PL_{cl}	Total number of plots in LU/LC class cl	dimensionless	A3-14, A3-17, A3-24, A3-34		calculated	only once at project start and when mandatory
Po	Anhydrous weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
$Population_t$	Equivalent number of forage-fed livestock at year t	number of heads	A4-1		calculated *ex ante*, measured *ex post*	annually
$PP_{i,t}$	Proportion of stratum i that is within the project area at time t	%	12		calculated	each renewal of fixed baseline period
PPx_l	Potential profitability of product Px at the location l (pixel or polygon)	$/t	1		calculated	each renewal of fixed baseline period
Ps	Saturated weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
Px	Product x produced in the reference region	dimensionless	1		measured or estimated from literature	each renewal of fixed baseline period
$r1$	Radius at the base of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
$r2$	Radius at the top of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
$RBSLRR\_avg_{i,t}$	Deforestation rate applicable to stratum i within the reference region at year t after $Toptimal_i$ years and during $Taverage_i$ years	%	4.b		calculated	each renewal of fixed baseline period
$RBSLRR\_opt_{i,t}$	Deforestation rate applicable to stratum i within the reference region at year t during the first $Toptimal_i$ years	%	4.a		calculated	each renewal of fixed baseline period

$RBSLRR\_sopt_{i,t}$	Deforestation rate applicable to stratum i within the reference region at year t after $Toptimal_i + Taverage_i$ and during $Tsub\text{-}optimal_i$ years	%	4.c		calculated	each renewal of fixed baseline period
$RBSLRR_{i,t}$	Percentage of remaining forest area at year t -1 in stratum i to be deforested at year t	%	11	Used as an alternative to $ABSLRR_{i,t}$ in baseline approach "c"	calculated	each renewal of fixed baseline period
RF_t	Risk factor used to calculate VCS buffer credits	%	25		estimated	each renewal of fixed baseline period
R_j	Root-shoot ratio appropriate for species, group of species or forest type j	dimensionless	A3-18		measured or estimated from literature	only once at project start
$R_{j,pl,tr}$	Root-shoot ratio, applicable to tree tr of species j in plot pl	dimensionless	A3-22		measured or estimated from literature	only once at project start
$S\$_x$	Selling price of product Px	$/t	1		measured or estimated from literature	each renewal of fixed baseline period
SLF_w	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
SPx_l	Selling point l of product Px	map	1		measured or estimated from literature	each renewal of fixed baseline period
t	1, 2, 3 … T a year of the proposed project crediting period	dimensionless	almost all equations		defined	
$t*$	the year at which the area $ABSLPA_{fcl,t}$ is deforested in the baseline case	dimensionless	A3-34		defined	
$t1$	Start date of the historical reference period	dimensionless				

$t2$	End date of the historical reference period	dimensionless				
$Taverage_i$	Number of years in which $Aaverage_i$ is deforested in the baseline case	yr	5		calculated	each renewal of fixed baseline period
$taverage_i$	Year at which $Taverage_i$ ends	yr	9, 11		calculated	each renewal of fixed baseline period
$TBab_j$	above-ground biomass of a tree of species, or species group, or forest type j	kg tree^{-1} or t tree^{-1}	A3-10		calculated	only once at project start
$TBab_{tr}$	Above-ground biomass of tree tr	kg tree^{-1} or t tree^{-1}	A3-11, A3-13, A3-21		calculated	only once at project start
$TCab_{tr}$	Carbon stock in above-ground biomass of tree $_{tr}$	kg C tree^{-1} or t C tree^{-1}	A3-11, A3-21		calculated	only once at project start
$TCbb_{tr}$	Carbon stock in below-ground biomass of tree $_{tr}$	kg C tree^{-1}	A3-16, A3-22		calculated	only once at project start and when mandatory
TC_v	Average Transport Cost per kilometer for one ton of product Px on land, river or road of type v	\$/t/km	1		measured or estimated from literature	each renewal of fixed baseline period
TD_v	Transport Distance on land, river or road of type v	\$/t/km	1		calculated	each renewal of fixed baseline period
$Thrp$	Duration of the historical reference period	yr	2		defined	only once at project start
$Toptimal_i$	Number of years since the start of the AUD project activity in which $Aoptimal$ in stratum i is deforested in the baseline case	yr	5		calculated	each renewal of fixed baseline period
$toptimal_i$	Year at which $Toptimal_i$ ends	yr	7, 8, 9		calculated	each renewal of fixed baseline period
tr	1, 2, 3, … $TRpl$ number of trees in plot pl	dimensionless	A3-13		measured or estimated from literature	only once at project start and when mandatory

$Tsub\text{-}optimal_i$	Number of years in which $Asub\text{-}optimal_i$ is deforested in the baseline case	yr	5		calculated	each renewal of fixed baseline period
v	1,2,3, …V type of surface on which transport occurs	dimensionless	1		measured or estimated from literature	each renewal of fixed baseline period
$V1_{i,t}$; $V2_{i,t}$; ...;$Vn_{i,t}$	Variables included in a deforestation model		11	Unit of each variable to be specified by the project proponent	measured or estimated from literature	each renewal of fixed baseline period
VBC_t	Number of Voluntary Buffer Credits deposited in the VCS Buffer at time t;	t CO_2-e	24, 25		calculated	annualy
VCU_t	Number of Voluntary Carbon Units (VCUs) to be made available for trade at time t	t CO_2-e	24		calculated	annualy
VEF	Volume Expantion Factor	dimensionless	A3-9		measured or estimated from literature	only once at project start
$VEX_{w,j,fcl,t}$	Volume of timber for product class w, of species j, extracted from within forest class fcl at time t	m^3	A3-34		measured or estimated from literature	only once at project start and when mandatory
$VOB10$	Volume Over Bark above 10 cm DBH	m^3	A3-9		measured or estimated from literature	only once at project start
$VOB30$	Volume Over Bark above 30 cm DBH	m3	A3-9		measured or estimated from literature	only once at project start
$Volume_{dc}$	Volume of laying dead wood in the density class dc	m^3	A3-30		measured or estimated from literature	only once at project start and when mandatory

V_{pl}	Commercial volume of plot pl	m³ plot⁻¹	A3-19		measured or estimated from literature	only once at project start and when mandatory
V_{tr}	Commercial volume of tree tr	m³	A3-18, A3-21		measured or estimated from literature	only once at project start and when mandatory
w	1, 2, 3 … W Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other);	dimensionless	A3-34		defined	only once at project start and when mandatory
WW_w	Wood waste for wood product class w. The fraction immediately emitted through mill inefficiency	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
XF	Plot expansion factor from per plot values to per hectare values	dimensionless	A3-12, A3-13, A3-16, A3-19, A3-20, A3-24		calculated	only once at project start and when mandatory