



VCS Methodology

VM0015

AVOIDED UNPLANNED DEFORESTATION

Version 1.2

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Sectoral Scope 14

Version 1.0 of this methodology was developed by the Amazonas Sustainable Foundation, BioCarbon Fund, Carbon Decisions International (CDI) and Institute for the Conservation and Sustainable Development of Amazonas (IDESAM).



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1 SOURCES

This methodology is based on the draft project description 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 of the draft methodology for “mosaic deforestation” developed by the BioCarbon Fund for the REDD project activity “Ankeniheny-Zahamena Biological Corridor” in Madagascar, adapted to include all kinds of “unplanned deforestation.” The Ankeniheny-Zahamena Biological Corridor baseline study, monitoring and project design documents are prepared by the Ministry of the Environment, Water, Forests and Tourism of Madagascar with the assistance of Conservation International and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund.

This methodology uses the latest versions of the following modules and tools:

- *VCS VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*
- *CDM Tool for testing significance of GHG emissions in A/R CDM project activities*
- *GOFC-GOLD 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*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology applies to projects that avoid unplanned deforestation (AUD). The baseline must include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agriculture or grazing activities, as long as the category is Avoiding Unplanned Deforestation according to the most recent VCS *Standard*.

The forest landscape configuration may be mosaic, frontier or a transition between the two. It is globally applicable except where the project area includes forested wetlands growing on peat (e.g., peat swamp forests).

Verified Carbon Units (VCUs) for reducing GHG emissions from avoided degradation and for enhancing carbon stock in forest that would be deforested in the baseline case are excluded from this methodology.

The eligible categories of project activity covered by this methodology are represented with the letters A to H in Table 1 and Appendix 1.

Table 1: Scope of the Methodology

		PROJECT ACTIVITY		
			Protection without logging, fuel-wood collection or charcoal production	Protection with controlled logging, fuel-wood collection or charcoal production
BASELINE	Deforestation	Old-growth without logging	A	B
		Old-growth with logging	C	D
		Degraded and still degrading	E	F
		Secondary growing	G	H
	No deforestation	Old-growth without logging	No change	Degradation
		Old-growth with logging	IFM	IFM-RIL
		Degraded and still degrading	IFM	IFM
		Secondary growing	No change	Degradation

TABLE NOTES

No deforestation If the baseline is not deforestation, the change in carbon stocks is not covered in this methodology.

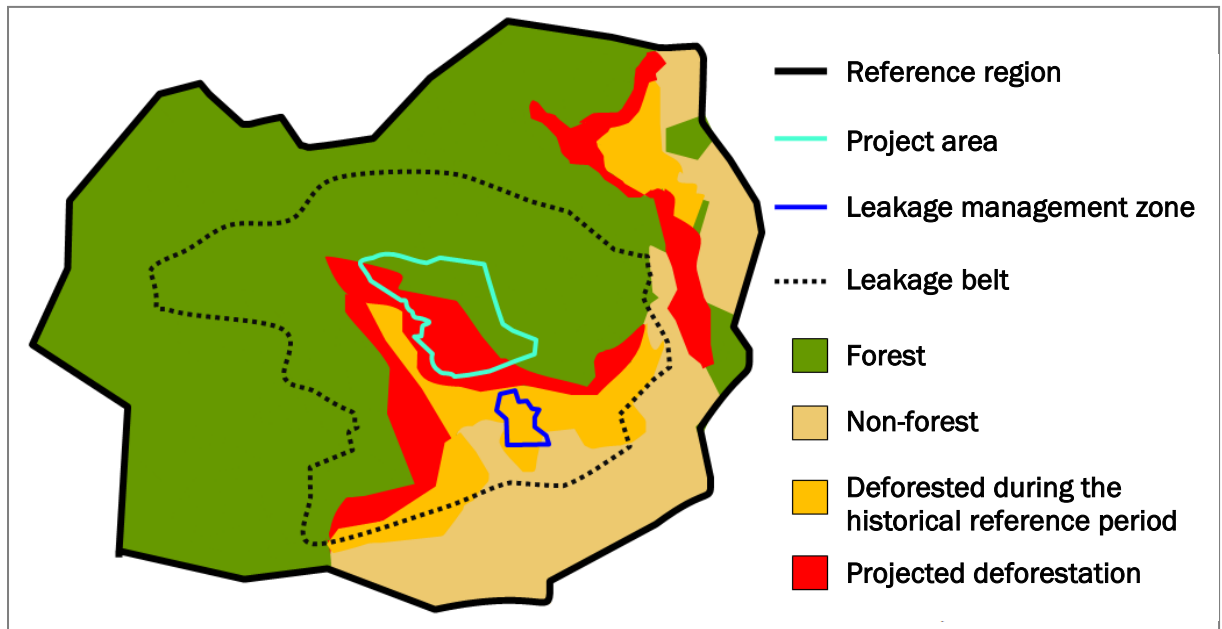
Accounting for carbon stock decrease due to timber harvesting, fuel-wood collection and charcoal production is mandatory in the project scenario where the decrease is significant. Accounting the increase of carbon stocks in forests that would be deforested in the absence of the project is conservatively omitted.

Leakage in this methodology is subject to monitoring, reporting, verification and accounting (MRV-A). However, where 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 Jurisdictional and Nested REDD+ (JNR) 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 *JNR Requirements* must be applied.

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

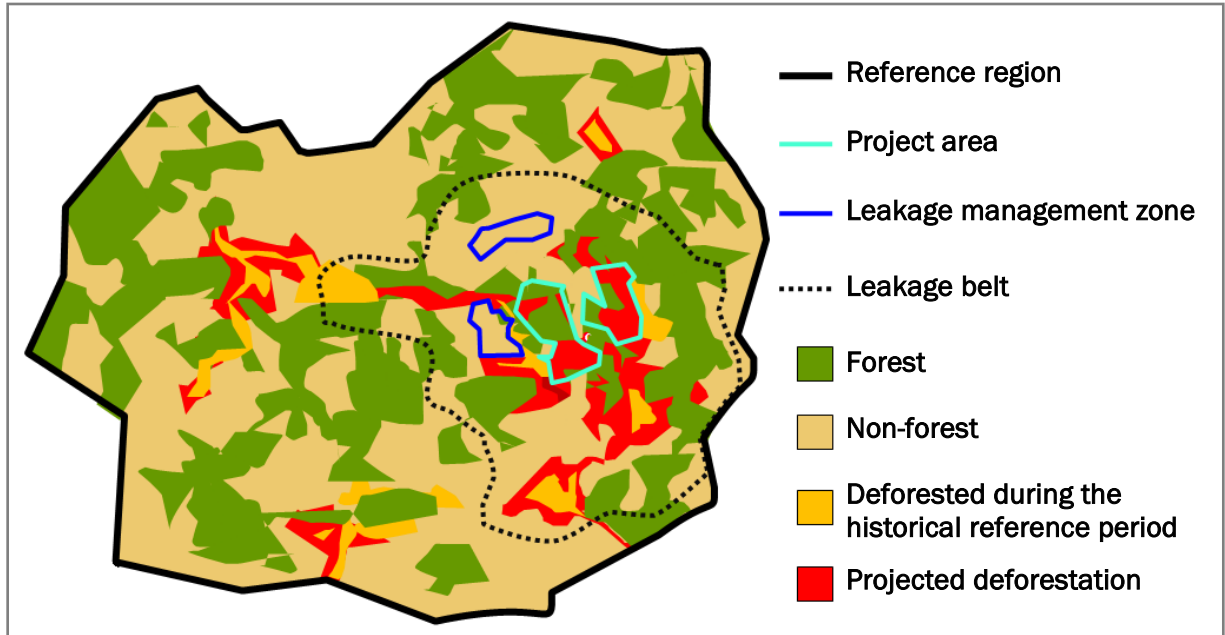
Figure 1: Spatial Domains Considered in this Methodology

Figure 1a: Frontier configuration



¹ Leakage management zone and leakage management area are used interchangeably in this methodology. Both correspond to the same spatial domain.

Figure 1b: 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 would be deforested in the baseline case.
- The “project area” is the area (or areas) under the control of project participants in which the AUD project activity will be implemented and GHG emission reductions accounted.
- The “leakage belt” is the area where deforestation avoided in the project area may be displaced as a result of project implementation. Any deforestation above the baseline projection that is monitored in the leakage belt is considered leakage.
- The “leakage management zone” 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. Leakage management zones must be non-forest land at the project start date.

The baseline projections must be revisited at the frequency set out in the most recent version of the *VCS Standard* and adjusted, as necessary, based on land use and land cover changes observed during the past period and changes at the level of agents, drivers 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 the “baseline validity period.” The baseline may be reassessed before the fixed baseline expires only where an applicable jurisdictional baseline becomes available.

Emissions of non-CO₂ gases in the baseline are conservatively omitted, except CH₄ emissions from biomass burning, which may be accounted where fire is the main technology used to deforest and where the project proponent considers that ignoring this source of emissions would substantially underestimate baseline emissions. However, CH₄ emissions from forest fires in the project case must be accounted where they are significant.

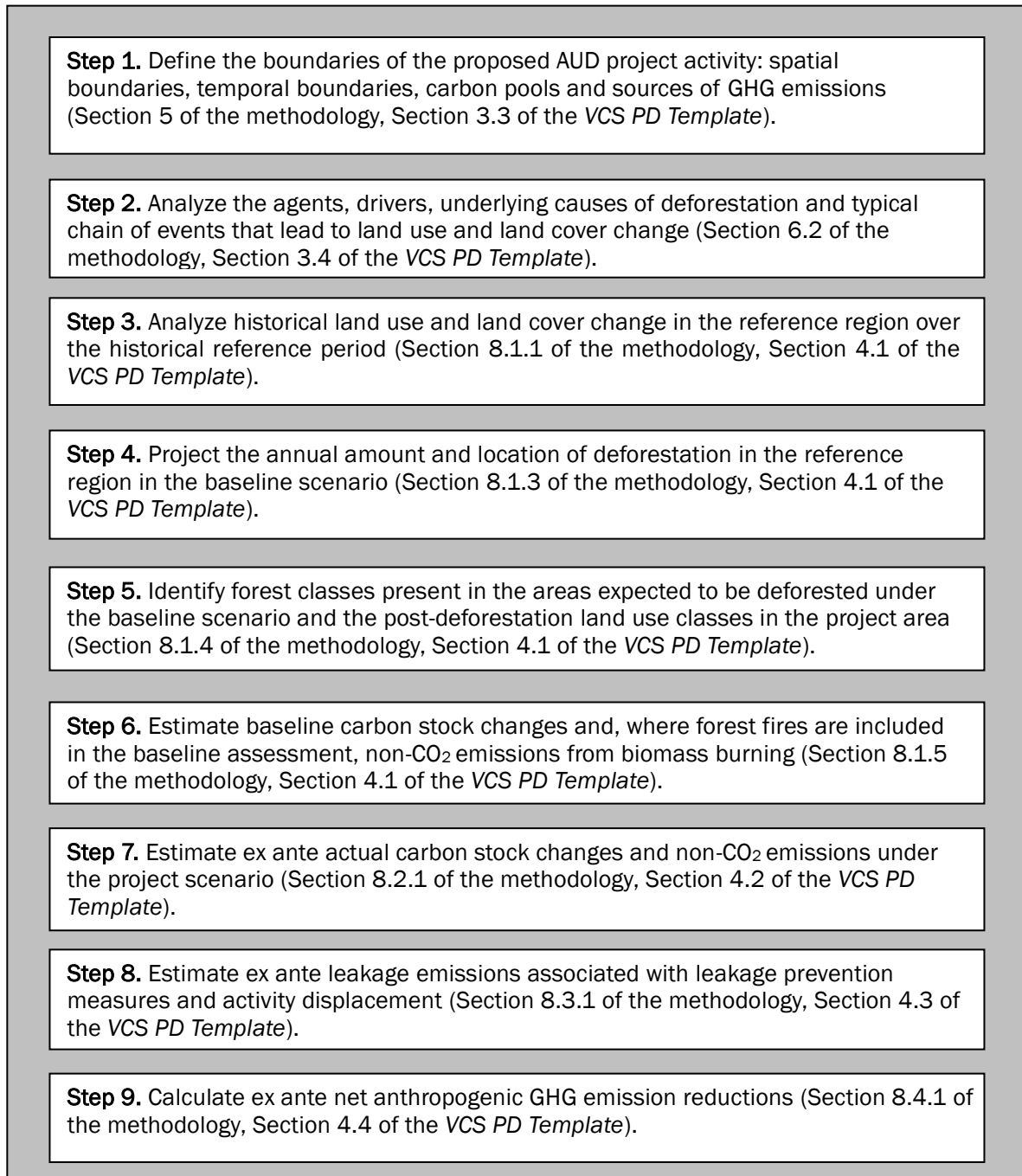
This methodology considers two potential sources of leakage:

- 1) **Activity-shifting leakage:** Where deforestation in the leakage belt is higher during project implementation than was projected under the baseline scenario, this is considered as activity displacement leakage, and the decrease in carbon stocks and increase in GHG emissions (where emissions from forest burning are included in the baseline) must be subtracted from the project's net GHG emissions reductions.
- 2) **Increased GHG emissions due to leakage prevention measures:** Where 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 zones, any decrease in carbon stocks and increase in GHG emissions associated with these activities must be estimated and subtracted from the project's net emissions reductions.

Any decrease in carbon stock or increase in GHG emissions attributed to the project activity must be accounted where significant, otherwise it may be neglected. Significance in this methodology is assessed using a specific tool described in Appendix 2: Testing Significance of GHG Emissions.

The nine steps for the ex ante calculation of net GHG emissions reductions are summarized in Figure 2. Project proponents should refer to each of these steps and their sub-sections using the same titles and numbers as indicated in the *VCS Project Description (PD) Template* so that application of the methodology may be transparently validated.

Figure 2: Steps for Ex Ante Calculation of Net GHG Emission Reductions and Indicative Reporting Section in the VCS Project Description Template



3 DEFINITIONS

In addition to the definitions set out in the *VCS Program Definitions*, the following definitions and acronyms apply to this methodology.

Activity data

Data on the magnitude of a human activity that results in emissions or removals taking place during a given period of time

Baseline validity period

The period of time for which a baseline is considered valid, as set out in the *VCS Standard*

Carbon density

The amount of carbon (as CO_{2e}) per hectare estimated to be present in the accounted carbon pools of a land use/land cover (LU/LC) class at year *t* (also referred to as carbon stock per hectare)

Category of LU/LC change

The change from one land use/land cover (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 LU/LC transitions. REDD methodologies deal with the following categories:

- Forest land to forest land (degradation and regeneration of forest land remaining forest land)
- Forest land to crop land (deforestation followed by agriculture)
- Forest land to grass land (deforestation followed by pasture)
- Forest land to settlements (deforestation followed by settlements)
- Forest land to wetlands (deforestation followed by wetlands)
- Forest land to other land (deforestation followed by other land)

Activities that convert non-forest land back to forest (e.g., crop land to forest land, grass land to forest land) are considered afforestation and reforestation and are excluded from this methodology. Activities that avoid forest degradation and activities that enhance forest carbon stocks both fall within the forest land to forest land category but are excluded from this methodology.

Deforestation

In addition to the definition in the *VCS Program Definitions*, in this methodology, deforestation is deemed to have occurred when at least one of the parameter values used to define “forest land” is reduced from above to below the threshold for defining “forest” for a period of time that

is longer than that used to define “temporarily unstocked.”² For example, where a country defines a forest as having crown cover greater than 30 percent and “temporarily unstocked” as a maximum period of three years, deforestation is not recorded until the crown cover is reduced below 30 percent for at least three consecutive years.³

Degradation (forest degradation)

In addition to the definition set out in the *VCS Program Definitions*, for this methodology, units of forest land subject to degradation are allocated to different forest classes over time, with each successive class having a lower carbon density. The difference in average carbon density between two contiguous forest classes should be at least 10 percent. The difference refers to the upper and lower levels of the confidence intervals of the two contiguous forest classes in the degradation sequence.

Emission factor

The difference between the carbon density of two LU/LC classes describing a category of LU/LC change

Forest

In addition to the definition set out in the *VCS Program Definitions* and the requirements of the *VCS Methodology Requirements*, for this methodology, “forest” is a land with woody vegetation consistent with the thresholds used to define “forest land” in the country where the project activity will be implemented. Where the country has submitted a REDD+ reference level to UNFCCC,⁴ the project must adopt the same thresholds for the vegetation indicators (minimum area, tree crown cover and height)⁵ used for defining “forests” in the country submission. Otherwise, the definition used to define “forest land” in the national GHG inventory should be used. In any case, the project must apply the most recent definition adopted by the host country.

² According to IPCC (GPG LULUCF, 2003, Chapter 4.2.6.2.) “The identification of units of land subject to deforestation activities requires the delineation of units of land that meet or exceed the size of the country’s minimum forest area (i.e., 0.05 to 1 ha); and have met the definition of forest on 31 December 1989; and have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced deforestation.”

³ Deforestation may be the result of an abrupt event (deforestation = forest to 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 to degraded forest to 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 crop production or grazing animals). Land use is thus not a reliable indicator for identifying a forest class or for defining a category of change.

⁴ Available at: <https://redd.unfccc.int/submissions.html>

⁵ “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 percent 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 stories 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 percent or tree height of 2–5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.”

Land defined as “forest land” may include areas that temporarily do not reach the thresholds used to define “forest land.” To distinguish between “non-forest” (and hence “deforested”) and “temporarily unstocked” areas in managed forests, the definition of “forest” should include the maximum period of time that the woody vegetation may remain below the thresholds used to define “forest land.” This maximum period may be specific to each category of land use/land cover change. For example, it may be zero years for conversion from “forest land to crop land,” but up to five or more years for transitions between forest classes (e.g., age classes).⁶

Areas covered with planted forests as well as with any other anthropogenic vegetation type that meets the definition of “forest” since the earliest date of the historical reference period used to assess deforestation may be considered “forest land.” “Forests” may be natural, semi-natural or anthropogenic and may include primary or old-growth forests (intact or logged), secondary forests, planted forests, agro-forestry and silvo-pastoral systems.

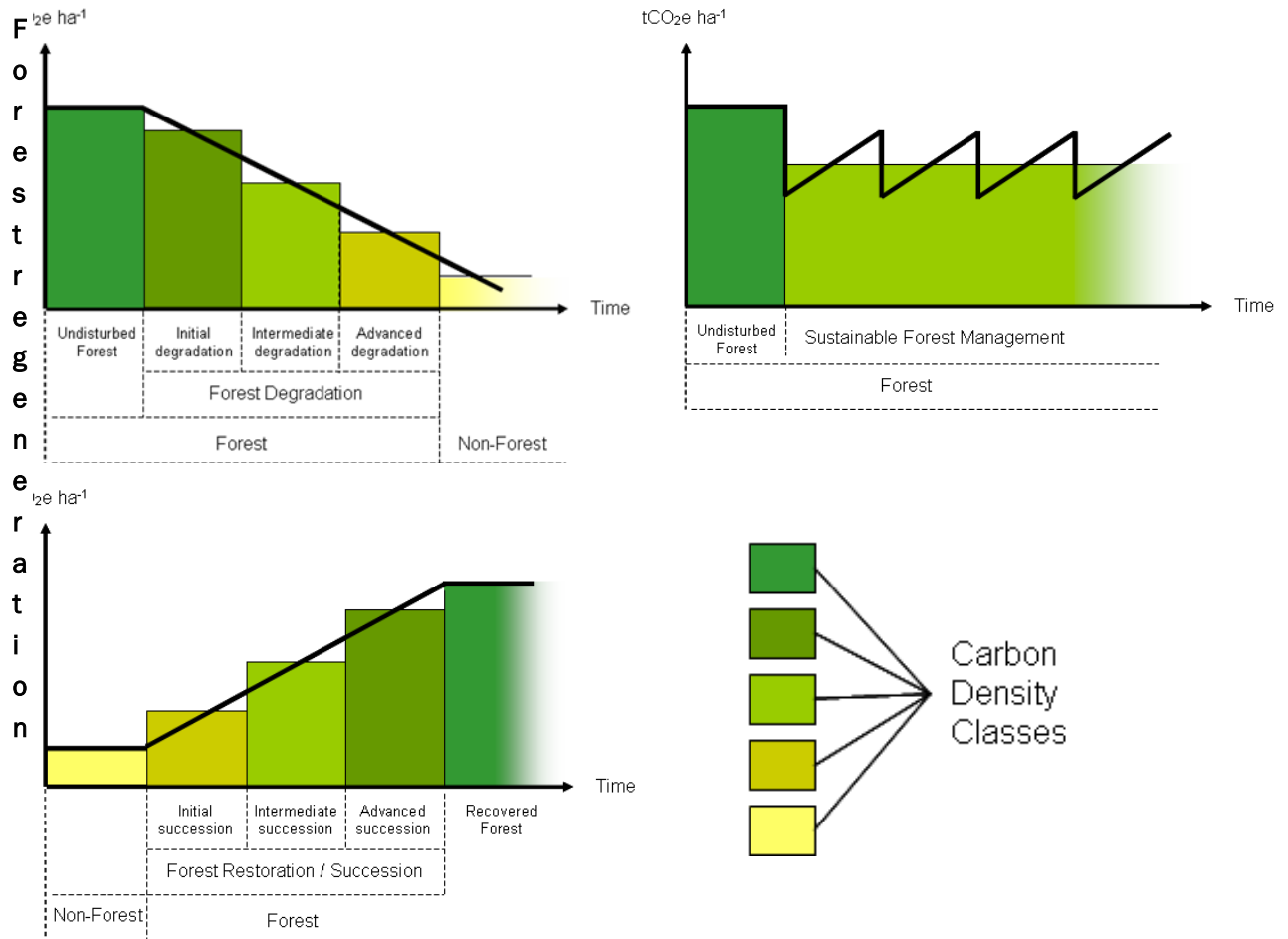
Forest management

Areas subject to sustainable forest management (with logging activities) represent a particular class of “degraded forest.” An undisturbed natural forest 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 are considered a degraded forest class.

Depending on the magnitude and timeframe of the carbon stock changes, managed forests may 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 (see Figure 3).

⁶ Project proponents should report how they distinguish between deforestation and areas that remain forest but where tree cover has been removed temporarily, notably areas that have been harvested or 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.

Figure 3: Carbon Density in “Forest Land Remaining Forest Land” (Living Tree Biomass)



Forest regeneration

“Forest land remaining forest land” and 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, each with successively higher carbon density. The difference in average carbon density between two contiguous forest classes should be at least 10 percent. The difference refers to the upper and lower levels of the confidence intervals of the two forest classes.

Frontier deforestation

The conversion of forest land to non-forest land occurring where the agricultural frontier expands as a result of improved access to forest into areas with relatively little human activity

Historical reference period

A fixed period of time during which factors must be considered in order to make future projections of deforestation, the duration of which is set out in the *VCS Methodology Requirements*

LU/LC class

A unique combination of land use and land cover having a specific carbon density at time t

LU/LC polygon

A discrete area falling into a single LU/LC class

Mosaic deforestation

Any landscape in which no patch of forest in the project area exceeds 1000 ha and the forest patches are surrounded by anthropogenically cleared land. Typically, a mosaic deforestation pattern occurs where the following conditions are met:

- 1) Population pressure and local land use practices produce a patchwork of cleared lands, degraded forests, secondary forests of various ages and mature forests;
- 2) All forests in the project area are similarly accessible; and
- 3) The agents of deforestation are present within the project area.

Peat

In addition to the definition set out in the *VCS Program Definitions*, in this methodology peat comprises organic soils with at least 65 percent organic matter and a minimum depth of 50 cm.

Planned deforestation

The legally authorized conversion of forest land to non-forest land occurring on a discrete area of land. Deforestation within an area may be planned (designated and sanctioned) or unplanned (unsanctioned). Planned deforestation includes 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; and plans to convert well-managed community-owned forests to other non-forest uses. Other forms of planned deforestation may include decisions by individual owners of land legally zoned for agriculture to convert their forest to crop production. These planned deforestation activities are a component of a land planning or management document and may be readily verified.

Zone

A stratum of the reference region containing a distinctive mix of final post-deforestation classes

4 APPLICABILITY CONDITIONS

This methodology applies to Avoiding Unplanned Deforestation project activities and is applicable globally under the following conditions:

- 1) Baseline activities include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agriculture or grazing activities as long as the category is Avoiding Unplanned Deforestation according to the most recent *VCS Standard*.
- 2) Project activities include one or a combination of the eligible categories defined in the description of the methodology scope (Table 1 and Appendix 1).
- 3) The project area includes one or a combination of forest types, such as, but not limited to, old-growth forest, degraded forest, secondary forests, planted forests or agro-forestry systems meeting the definition of “forest.”
- 4) At the project start, the project area includes only land qualifying as “forest” for a minimum of 10 years prior to the project start date.
- 5) The project area may include forested wetlands (such as bottomland forests, floodplain forests, mangrove forests) where they do not grow on peat (as defined in Section 0).

This methodology is not applicable under the following conditions:

- 6) The project area includes forested wetlands growing on peat (e.g., peat swamp forests).

5 PROJECT BOUNDARY (STEP 1)

The purpose of this step is to define the spatial and temporal boundaries, carbon pools and sources of greenhouse gas (other than carbon stock changes) in the project.

5.1 Spatial Boundaries

Define the boundaries of the following spatial features: reference region, project area, leakage belt, leakage management zones and forest. The reference region is the largest unit of land. The project area, leakage belt and leakage management zones are subsets of the reference region. The criteria used to define their boundaries must be described and justified in the PD. The project proponent must provide digital (vector-based) files of these features in a format specified by the most recent version of the *VCS Standard*.

5.1.1 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 should contain strata with agents, drivers and patterns of deforestation that in the 10-year period prior to the start date of the proposed AUD project activity are similar to those expected to exist within the project area. A geographic area is relevant for determining the baseline scenario of the project area where it represents a credible proxy for future deforestation patterns in the project area.

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

- 1) The reference region must be a single contiguous area that encompasses the project area and the leakage belt.
- 2) The reference region must be larger than the project area. For projects equal to or larger than 100 000 ha, the reference region must be five to seven times larger than the project area. For projects smaller than 100 000 ha, the reference region must be 20-40 times the size of the project area.⁷
- 3) The boundaries of the reference region must be unbiased and coincide with a combination of natural and administrative boundaries so that land use and land cover related policies are consistent across the reference area. Forests located in the same geography should not be arbitrarily excluded. High deforestation areas should not be arbitrarily included in the reference region. The rationale behind the reference region delineation must be described in the PD.
- 4) Where a project area includes an entire forest island, the reference region must include other islands or forested landscapes with similar conditions.
- 5) 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 must be divided into strata, each representing proxies for the chronosequence of current and future conditions within the project area. The boundary of such strata may be static (fixed during a baseline validity period) or dynamic⁸ (changing every year), depending on the modeling approaches used.

Once the boundary of the reference region is delineated, the project must demonstrate, using verifiable data, that the conditions determining the likelihood of deforestation within the project area are similar, or expected to become similar, to those found in the reference region.

The project area must be 100 percent forested at the project start date. A 5-km buffer (leakage belt) surrounding the project area should be delineated to allow demonstration of similarity between the reference region and non-forested areas adjacent to the project area. Alternatively, the area may be delineated using mobility analysis. Where mobility analysis has been used to

⁷ Following Brown et al. (2007)

⁸ With shifting boundaries, according to modeled changes at the level of driver variables such as population, infrastructure and others to be determined by the project proponent.

delineate the leakage belt, the same analysis should be used to demonstrate the likelihood of deforestation within the project area.

Similarity of deforestation risk in the reference region and project area must be demonstrated using three criteria: the agents and drivers of deforestation, landscape configuration and ecological conditions and socio-economic and cultural conditions:

- 1) The main agents and all drivers of deforestation expected to cause deforestation within the project area in the absence of the proposed AUD project activity must exist or have existed elsewhere in the reference region. The following requirements must be met:
 - a) Deforestation agent groups (as identified in Section 6.2.1) expected to encroach into the project area exist or have existed and caused deforestation elsewhere in the reference region during the historical reference period.
 - b) Settlement density (settlements/km²) and road density (m/km²) in the reference region at the start of the historical reference period is the same, less than or does not exceed by more than 20 percent the settlement density surrounding the project area, at the project start date. Where new or improved infrastructure (e.g., roads, railroads, bridges, hydroelectric reservoirs) is expected to be developed near or inside the project area,⁹ the reference region includes a stratum where such infrastructure was built in the past and where the impact on forest cover was similar to that expected from new or improved infrastructure in the project area. Where the project area is adjacent to navigable rivers, their density (m/km²) in the reference region is the same, less than or does not exceed by more than 20 percent the navigable river density in and surrounding the project area.
 - c) Any spatial deforestation driver considered relevant according to Section 6.2.2 (e.g., resettlement programs, mining and oil concessions) exists or has existed elsewhere in the reference region. The historical impact of such drivers is similar to that expected in the project area.

Agents and drivers that are present in the reference region, but unlikely to be present in the project area must be identified, and the area affected by them removed from the reference region. For example, since planned deforestation in the baseline case is excluded from the project area, designated and planned deforestation must also be excluded from the reference region.

- 2) The following landscape configuration and ecological conditions must be satisfied:
 - a) At least 90 percent of the project area has forest classes or vegetation types that exist in at least 90 percent of the rest of the reference region.

⁹ Areas of planned deforestation in the baseline case must be excluded from the project area.

- b) At least 90 percent of the project area is within the elevation range of at least 90 percent of the rest of the reference region.
 - c) The average slope of at least 90 percent of the project area is within ± 10 percent of the average slope of at least 90 percent of the rest of the reference region.
 - d) The average annual rainfall in at least 90 percent of the project area is within ± 10 percent of the average annual rainfall of at least 90 percent of the rest of the reference region.
 - e) At least 90 percent of the project area has soil types that exist in at least 90 percent of the reference region.
- 3) The following socio-economic and cultural conditions must be met:
- a) The legal status of the land (e.g., private, forest concession, conservation concession) prevalent in the reference region is demonstrated to be similar to that expected to be prevalent in the project area under the baseline case. Where 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).
 - b) The land-tenure system prevalent in the project area in the baseline case is prevalent in the reference region.
 - c) Current and projected classes of land use in the project area are found elsewhere in the reference region.
 - d) The project area is governed by the same policies, legislation and regulations that apply in the reference region.
 - e) The proportion of urbanized and agriculture-based population within the reference region is within 10 percent of the proportion in the areas surrounding the project area.

Any differences in land tenure or legal status systems between the project area and reference region must not affect the drivers of deforestation and degradation or the operation of the agents of deforestation and degradation.

At baseline reassessment, the project must demonstrate that the reference region remains a credible proxy of deforestation patterns in the project area during the new baseline validity period. The same conditions as above must be met. Any changes to the reference region that lead to less conservative baseline GHG emissions should be justified by the revised analysis of agents and drivers and demonstrated using verifiable evidence.

5.1.2 Project Area

The project area is the area(s) of land under control of the project proponent and where the project activities will be carried out. The project area must be exclusively forest land at the project start date.

Any area affected or expected to be affected by planned deforestation under the baseline scenario must be excluded from the project area. Planned deforestation may only be included in the project area where it is a project activity and accounted for in the project GHG emissions.

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 VCUs, but they may be included where the project proponent considers that future baseline reassessments are likely to indicate future deforestation threats that it is not possible to demonstrate at the time of validation.

Where less than 80 percent of the total proposed area of the project is under the project proponent's control at validation, new discrete units of land may be integrated into an existing project area where included in the monitoring report at the time of the first verification. Refer to the most recent version of the *VCS Standard* for the full rules and requirements regarding control over the entire project area at validation.

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

- 1) Name (or names, as appropriate) of the project area;
- 2) Physical boundary of each discrete area of land included in the project area in a file format specified by the *VCS Standard*;
- 3) Description of current land tenure and ownership, including any legal arrangement related to land ownership and the AUD project activity; and
- 4) List of the project participants and brief description of their roles in the proposed AUD project activity.

5.1.3 Leakage Belt

Leakage is subject to MRV-A in an area called the "leakage belt" in this methodology.

The leakage belt is the land area(s) surrounding or adjacent to the project area where baseline activities may be displaced due to the project activities implemented in the project area.

Two methods may be used to delineate the leakage belt: opportunity cost analysis (Option I) or mobility analysis (Option II).

The leakage belt boundary must be reassessed at the end of each baseline validity period, as opportunity costs and mobility parameters are likely to change over time. It must also be reassessed when a VCS AFOLU project is registered that is located in the project's leakage belt area as specified in Section 5.1.3.3. Changes in the leakage belt boundary must be reported

and verified as a PD deviation. Any time the leakage belt boundary is reassessed, the baseline emissions must be recalculated to reflect the change.

Where opportunity costs or mobility parameters are projected for each future year, the boundary of the leakage belt that is adopted for the whole duration of the baseline validity period must be that projected for the last year of the baseline validity period.

5.1.3.1 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 to show that at least 80 percent of the area deforested in the reference region (or some of its strata) during the historical reference period has occurred at locations where deforestation was profitable (i.e., for at least one product, $PPx_i \geq 1$). Alternatively, use published studies, surveys and other credible and verifiable sources of information. If Option I is not applicable, use Option II.

Where the main motivation is economic profit, agents not allowed to deforest within the project area will shift deforestation outside the project area only if doing so brings economic benefits to them. Based on this rationale, leakage may 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 lower than the price of the products (i.e., opportunity costs are > 0). To identify this land area, do the following:

- 1) List the main land uses, such as cattle ranching and/or crops, that deforestation agents are likely to implement within the project area in the baseline case.
- 2) Find credible and verifiable sources of information on the following variables:
 - a) Sx = Average selling price per tonne of 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 (e.g., meat, crop type A, crop type B)
 - b) SPx_i = Most important selling points (spatial locations) for each main product Px in the reference region
 - c) PCx_i = Average in situ production costs per tonne of product. Stratify the reference region as necessary in i strata, as production costs may vary depending on local conditions (e.g., soil, technology available to the producer)
 - d) TC_v = Average transport cost per kilometer for one tonne of product Px transported on different types of land uses (e.g., pasture, cropland, forest), roads, railroads and navigable rivers using the most typical transport technology available to the producer

Note – for simplicity, current prices and costs may be used to project opportunity costs. Price and cost projections must only be used only where reliable and verifiable sources of information are available.

- 3) Using a geographic information system (GIS), generate for each main product a surface representing the minimum transport cost of one tonne of product to the most important

selling points within the reference region. Do this by considering the most common transport technology available to deforestation agents.

- 4) For each main product, add to the surface created in (3) above the average in situ cost for producing one tonne of product. The result is a surface representing the total cost of producing and bringing to the market one tonne of product.
- 5) For each main product, subtract from the average price of one ton of product the total cost surface created in (4) above. The result is a surface representing potential profitability of each product.

Note – where several products may be produced at the same site, the maximum value of all potential profitability surfaces will represent the opportunity cost of conserving the forest.

- 6) The leakage belt is the area where the potential profitability surface created in (5) has a positive value at the last year of the baseline validity period.

The above procedure may be summarized as follows:

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

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

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 tonne of product Px in stratum i (\$/t)
TCv	=	Average transport cost per kilometer for one tonne 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 on which transport occurs (dimensionless)

Note – Option I assumes 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, participatory rural appraisal, literature, and/or other verifiable sources of information. Where the evidence collected is not convincing, use Option II (mobility analysis).

5.1.3.2 Option II: Mobility Analysis

Mobility analysis may always be used but must be used where Option I is not applicable (i.e., where less than 80 percent 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). In Option II, the potential mobility of deforestation agents is assessed using multi-criteria analysis. The following steps must be applied:

- 1) Using historical data, expert opinion, participatory rural appraisal, 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 Section 6.2.1. The overall suitability of the land for the deforestation agents' activities must be considered.

- 2) For each criterion, generate a map using GIS.
- 3) Using multi-criteria analysis, determine the boundary of the leakage belt. Justify any assumption and weight assigned to the individual criteria.
- 4) Methods used to perform the analysis must be transparently documented and presented to the validation/verification body (VVB) at validation.
- 5) The assumptions made for the analysis must be supported by historical data.

5.1.3.3 Consideration of Other VCS AFOLU Projects

Where 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:

- 1) Exclude the project area of the other VCS AFOLU project(s) from the leakage belt area of the proposed AUD project.
 - a) The exclusion must enter into force at the registration date of the other project
 - b) Carbon accounting must consider the exclusion of the project area of the other project beginning with the start date of the other projects
 - c) An excluded area must 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.
- 2) Where 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. For common carbon pools and sources of GHG emissions only, the boundary of the leakage belt may 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 are no overlaps or 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 must be similar to the percentage of baseline deforestation of the project relative to the total baseline deforestation of all projects:

$$\%LKBA = BLDA / (BLDA + BLDB + \dots + BLDN) \quad (2a)$$

$$\%LKBB = BLDB / (BLDA + BLDB + \dots + BLDN) \quad (2b)$$

...

$$\%LKBN = BLDN / (BLDA + BLDB + \dots + BLDN) \quad (2n)$$

Where:

%LKBA	=	Percentage of overlapping leakage belts area assigned to Project A (%)
%LKBB	=	Percentage of overlapping leakage belts area assigned to Project B (%)
%LKBN	=	Percentage of overlapping leakage belts area assigned to Project N (%)
BLDA	=	Total area of projected baseline deforestation during the baseline validity period of Project A (see PD of project A) (ha)
BLDB	=	Total area of projected baseline deforestation during the baseline validity period of Project B (see PD of project B) (ha)
BLDN	=	Total area of projected baseline deforestation during the baseline validity period of Project N (see PD of Project N) (ha)

Note – the proponents of the different projects must 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, where they decide to use this rule, the area of the overlapping leakage belts assigned to Project A must be the closest to the boundary of Project A; that assigned to Project B must be the closest to the boundary of Project B and so on (the area of the overlapping leakage belts assigned to Project N must 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 periodic verification. A project may report a smaller leakage belt only where the part that is excluded is included in another VCS-registered project's leakage belt.
- e) Where the proponents of the different projects disagree on splitting the overlapping leakage belt area, each project must include the overlapping areas in its leakage belt.
- f) A “leakage belt agreement” between the proponents of the different projects must be signed and presented to the VVB at validation/verification. The agreement must include maps of the agreed leakage belts, and each project must have a digital copy of these maps in the projection and GIS software formats used in each project.
- g) Where a project ends or has not completed a verification for more than five consecutive years, the other projects participating in the “leakage belt agreement” must amend the agreement to ensure that the whole area of the originally overlapping leakage belts is always subject to MRV-A. The amendment is subject to VVB verification. If no amendment is made, the proposed project must include in its leakage belt the land area that is no longer subject to MRV-A by any another VCS project.

5.1.4 Leakage Management Zones

These are non-forest areas located outside the project boundary in which the project proponent intends to implement activities (such as afforestation, reforestation or enhanced crop and grazing land management) that will reduce the risk of activity displacement leakage. Such areas must be delineated according to existing management plans or other plans related to the proposed AUD project activity that must be made available to the VVB at validation. The boundary of leakage management zones must be clearly defined and digital (vector-based) files in any format specified by the *VCS Standard* must be provided. A clear description must accompany the file, and the metadata must contain all necessary projection reference data. The boundary of the leakage management zone must be reassessed and validated at each baseline validity period.

5.1.5 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 are projected. The ex post boundary of forest land in the project area and leakage belt will be subject to periodic MRV.

To define the forest boundary, specify:

- 1) The definition of forest that used for measuring deforestation during the project crediting period
- 2) The minimum mapping unit (MMU). The MMU of LULC maps created using remote sensing imagery must not be larger than one hectare irrespective of forest definition.

An initial forest cover 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 Section 8.1.3 will generate one such map for each future year of the baseline validity period and, optionally, the project crediting period.

Areas covered by clouds or shadows must be analyzed by complementing the analysis of optical sensor data with non-optical sensor data. However, where some obscured areas remain for which no spatially explicit and verifiable information on forest cover is available nor for which it is possible to collect data (using ground-based or other methods), such areas must be excluded (masked out). This exclusion is either:

- a) **Permanent**, unless it may be reasonably assumed that these areas are covered by forests (e.g., due to their location); or
- b) **Temporary**, where information is 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 GHG emission reductions for 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.”

5.2 Temporal Boundaries

Define the temporal boundaries listed below.

5.2.1 Start and End Dates of the Historical Reference Period

The historical reference period start date should not be more than 10 years before the project start date. The end should be as close as possible to the project start date.

5.2.2 Start Date of the AUD Project Activity Crediting Period

The length of the project crediting period is set out in the most recent version of the *VCS Program Definitions*.

5.2.3 Start and End Dates of the First Baseline Validity Period

The baseline validity period is set out in the most recent *VCS Standard*. The start and end dates must be defined.

5.2.4 Monitoring Period

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

5.3 Carbon Pools

The greenhouse gases included in or excluded from the project boundary are shown in Table 2.

Table 2: Carbon Pools Included in or Excluded from the Boundary of the Proposed AUD Project Activity

Carbon pools	Included/TBD/Excluded	Justification/Explanation of choice
Above-ground biomass	Tree: Included	Carbon stock change in this pool is always significant.
	Non-tree: TBD	Must be included in categories where the baseline final land cover is perennial crop
Below-ground biomass ⁺	TBD	Optional
Dead wood ⁺	TBD	Mandatory if this carbon pool is greater in the baseline final land cover (post-deforestation) than project scenario, and unless demonstrated insignificant. Otherwise, can be conservatively omitted

Carbon pools	Included/TBD/Excluded	Justification/Explanation of choice
Harvested wood products ⁺	Included	To be included where significant
Litter	TBD	Optional –conservative to exclude
Soil organic carbon ⁺	TBD	Recommended where forests are converted to cropland. Not to be measured in conversions to pastures or perennial crop according to the latest version of the <i>VCS Methodology Requirements</i>

TABLE NOTES

- TBD To be decided by the project proponent; may be excluded only where exclusion does not lead to a significant overestimation of the net GHG emission reductions of the AUD project activity.
- + The *VCS Methodology Requirements* require methodologies to consider the decay of carbon in soil carbon, belowground biomass, dead wood and harvested wood products. The immediate release of carbon from these pools in the baseline case must not be assumed.

The significance of pools must be determined as per the latest *VCS Methodology Requirements*. It must be assessed ex ante or at baseline reassessment for a specific baseline validity period, as well as at verification for a specific monitoring period. Appendix 2 should be used to test significance of pools.

Carbon pools that are expected to decrease their stocks in the project scenario compared to the baseline must be included where their exclusion leads to a significant overestimation of the net GHG emission reductions generated during the baseline validity period.

Where a carbon pool is included in the baseline accounting, it must also be included in project scenario and leakage accounting.

Carbon pools considered insignificant according to the latest *VCS Methodology Requirements* may always be neglected.

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

Non-tree biomass must be included where 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 crops are commonly planted in the region where the project area is located. The significance criterion must apply.

Below-ground tree biomass is recommended for inclusion, as it usually represents between 15 and 30 percent of above-ground biomass.

Harvested wood products must be included where removal of timber is associated with significantly more carbon stored in long-term wood products in the baseline than the project scenario, and where the pool is included in the project scenario. The significance criterion must apply. When included, the short-lived fraction (decaying in less than 3 years) is assumed to decay immediately at the year of deforestation ($t = t^*$); the medium-lived fraction (decaying in 3–100 years) is assumed to decay over a 20-year period; and the long-lived fraction is assumed to never decay (i.e., it does not result in emissions).

The exclusion of a carbon pool is conservative in most cases except where the carbon stock in the pool is higher in the baseline than in the project scenario.

The inclusion of a carbon pool is recommended (but not mandatory) where the pool is likely to represent an important proportion (more than 10 percent) 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.

Where the exclusion of a carbon pool is not conservative, demonstrate that the exclusion will not lead to a significant overestimation of the net GHG emission reductions. Where the exclusion is significant, the pool must be included.

In most cases the same carbon pools must be considered for all categories of LU/LC change. However, different carbon pools may be included for different categories of LU/LC change 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.

Within a LU/LC-change category, the same carbon pools must be selected for the two classes involved. Table 68 in Appendix 4: Methods to Estimate Emissions from Enteric Fermentation and Manure Management⁰ provides an indication of the level of priority for including different carbon pools depending on the LU/LC change category.

There is further guidance on the selection of carbon pools in the most recent version of the GOF-C-GOLD REDD sourcebook; details are given in Appendix 3.

5.4 Sources of GHG Emissions

The two sources of GHG emissions listed in Table 3 are considered in this methodology.

Table 3: Sources and GHG to be Included in or Excluded from the Boundary of the Proposed AUD Project Activity

Sources	Gas	Included/TBD/Excluded	Justification/Explanation of choice
Biomass burning	CO ₂	Excluded	Counted as carbon stock change
	CH ₄	TBD	See guidance below
	N ₂ O	Excluded	Considered insignificant* according to the <i>VCS Methodology Requirements</i>
Livestock emissions	CO ₂	Excluded	Not a significant* source
	CH ₄	TBD	See guidance below
	N ₂ O	TBD	See guidance below

TABLE NOTES

TBD To be decided by the project proponent; may be excluded only where exclusion does not lead to a significant overestimation of the net GHG emission reductions of the AUD project activity.

* Carbon pools and sources that account for more than 5 percent of the total GHG benefits generated must be considered “significant.” To determine significance, Appendix 2 must be used.

Emissions sources that are expected to increase in the project scenario compared to the baseline must be included where their exclusion leads to a significant overestimation of the total net GHG emission reductions generated during the baseline validity period.

Sources considered insignificant according to the latest *VCS Methodology Requirements* may always be neglected.

The inclusion of a source is recommended (but not mandatory) where the source is likely to represent an important proportion (more than 10 percent) of the total emissions reductions attributable to the project activity (“expected magnitude of change”).

A source may only be excluded where 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 to be monitored ex post.

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

In the baseline scenario, non-CO₂ emissions from fires used to clear forests may be counted where sufficient data are available for estimation. However, accounting for these emissions

may be conservatively 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 GHG emissions than the baseline activities implemented prior to and after deforestation on the deforested lands. Therefore, excluding certain sources of GHG emissions, such as fossil fuel consumption, will not cause an overestimation of net GHG emission reductions. However, non-CO₂ emissions from forest fires must be counted in the project scenario where they are significant.

In leakage estimation, GHG emissions of sources attributable to leakage prevention measures (e.g., those implemented in leakage management zones) and that increase compared to pre-existing GHG emissions count as leakage and should be estimated and counted where they are significant. Non-CO₂ emissions from displaced baseline activities, which are conservatively omitted in the baseline, may be ignored, as they would be similar to baseline emissions in the worst-case scenario. However, where non-CO₂ 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.

6 BASELINE SCENARIO

6.1 Determination of the Most Plausible Baseline Scenario

Determination of the most plausible baseline scenario builds on the outcome of the additionality analysis (Section 7) and must be consistent with the description of conditions prior to the project start date. *VT0001* must be used to assess the project additionality. The stepwise approach below must be followed in addition to *VT0001* to determine the most plausible baseline scenario.

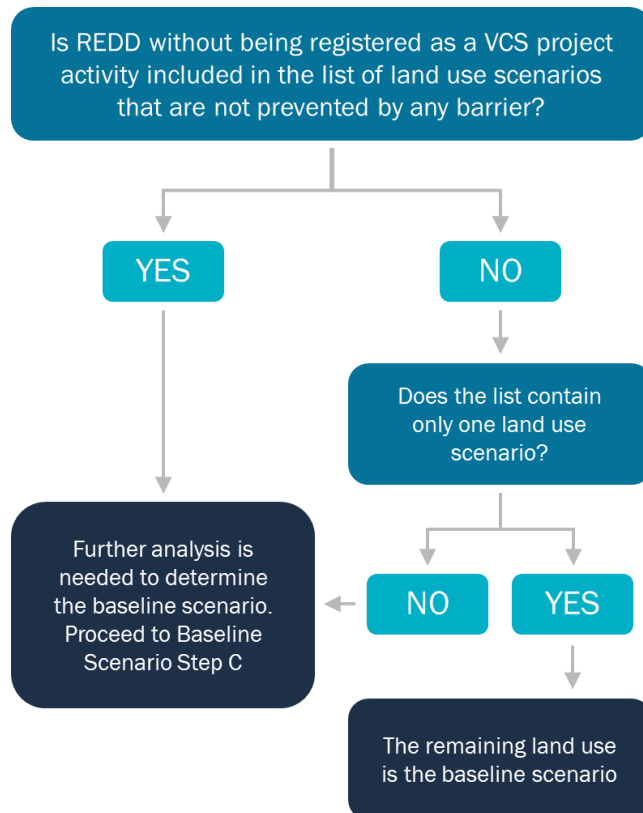
Step A: Reuse the plausible alternative land use scenarios to the REDD project activity that have been listed as an outcome of Sub-step 1b of the additionality tool *VT0001*.

Unless it has been demonstrated that any of these land use scenarios are not credible or do not comply with all mandatory applicable legislation and regulations as required by *VT0001* Sub-step 1b, the list of plausible alternative land use scenarios must include at least:

- 1) Continuation of the pre-project land use;
- 2) Project activity performed on the land within the project boundary without being registered as a VCS REDD project; and
- 3) Activities similar to the proposed project activity on at least part of the land within the project boundary of the proposed REDD project.

Step B(1): Where the *VT0001* barrier analysis is used to demonstrate additionality, apply the decision tree in Figure 4 to the list of all alternative land use scenarios from Step 1 that are not prevented by any barrier.

Figure 4: Barrier Analysis Decision Tree



Step B(2): Where the *VT0001* investment analysis is used to demonstrate additionality, and if at least one land use scenario generates financial benefits other than carbon revenues, select the baseline scenario as below:

- 1) Where *VT0001* Option I is used, the baseline scenario is the land use scenario with the lowest costs over the crediting period). Option I may only be applied where the alternative scenarios do not include revenues.
- 2) Where *VT0001* Option II is used, the baseline scenario is the most economically or financially attractive land use scenario (i.e., the scenario with the most favorable financial indicator such as internal rate of return).
- 3) Where *VT0001* Option III is used and none of the alternative land use scenarios have a financial indicator that meets the benchmark, the baseline scenario is the continuation of the pre-project land use. Where Option III is used and at least one of the land use scenarios has a financial indicator that meets the benchmark, the baseline scenario is the scenario that has the most favorable financial indicator (e.g., internal rate of return, net present value or cost-benefit ratio).

Step C: Where barrier analysis is used to demonstrate additionality but does not allow determination of the baseline scenario, implement one of the following:

- 1) An investment analysis following VT0001 Option II (regardless of whether it has been used to demonstrate additionality). Select the most plausible baseline as specified in Step B(2) above; or
- 2) Through qualitative analysis, estimate the baseline GHG emissions for each alternative land use scenario that is not prevented by any barrier. The baseline scenario is the land use scenario that allows for the lowest baseline GHG emissions. Estimates must be based on publicly available default factors and standards, such as the *IPCC 2006 Guidelines for National GHG Inventories* and its *2019 Refinements* or the *IPCC 2003 Good Practice Guidelines for LULUCF*. All other data used must be publicly available and must come from recognized, credible sources, such as peer-reviewed literature.

Quantification of GHG emissions under the selected baseline scenario must follow the applicable and relevant activity-type module(s).

6.2 Description of Baseline Scenario (Step 2): Analysis of Agents, Drivers and Underlying Causes of Deforestation and Their Likely Future Development

Once the most plausible baseline scenario is determined, it must be described through a detailed analysis of the agents, proximate causes, drivers and underlying causes of deforestation.¹⁰

Understanding “who” is deforesting and what drives their decision is necessary to understand the risk of activity-shifting leakage and to design effective measures to address deforestation. The analysis of agents and drivers of deforestation is also key to estimate the quantity and location of future deforestation. For example, the analysis must be referenced when selecting the approach to project future deforestation quantity (Section 8.1.3.1) and the variables to be included in the spatialization model (Section 8.1.3.20).

The analysis described in this section must be summarized in the PD.

The baseline scenario description must be supported by evidence such as existing studies, maps (including the jurisdictional forest cover benchmark map (FCBM) and risk map), expert consultations, field surveys (such as participatory rural appraisal) and other verifiable sources of information.

Notwithstanding other rules and requirements, the most plausible baseline scenario described in this section must at minimum be consistent with and referred to when describing the

¹⁰ See Angelsen and Kaimowitz (1999) and Chomitz et al. (2006) for comprehensive analysis of deforestation agents and drivers.

conditions prior to project initiation, identifying the stakeholders to be engaged and consulted, delineating the reference region (Section 5.1.1), selecting carbon pools and estimating the post-deforestation carbon stocks (Sections 5.3, 5.4 and 8.1.5), delineating the leakage belt (Section 5.1.3), quantifying the risk of leakage (Section 8.3), estimating ex ante project effectiveness at reducing deforestation (Section 8.2.1.1) and assessing the non-permanence internal and external risks following the most recent version of the *VCS AFOLU Non-Permanence Risk Tool*.

6.2.1 Identification of Deforestation Agents

Identify the main groups of deforestation agents (e.g., farmers, ranchers, loggers) and their relative importance (i.e., the amount of historical LU/LC change that may be attributed to each). Use existing studies, the maps prepared in Step 3 (Section 8.1.1.4), expert consultations, field-surveys and other verifiable sources of information, as needed.

It may be possible to determine the relative importance of each agent from the LU/LC change matrix developed in Section 8.1.1.4, since each agent usually converts forests for a specific purpose (e.g., cattle ranching, cash-crop production, subsistence farming).

Where the relative importance of different agents is spatially correlated (e.g., small farmers are concentrated in hill areas and ranchers on plains), 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 projection accuracy.

For each identified agent group, provide the following information:

- 1) Name of the main agent group or agent;
- 2) 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 deforested the reference region during the historical reference period and why it is expected to deforest the project area during the baseline validity period;
- 3) Brief assessment of the most likely changes in population size of the identified main agent groups in the reference region, project area and leakage belt;
- 4) Statistics on historical deforestation attributable to each main agent group in the reference region, project area and leakage belt.

6.2.2 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 must be distinguished:

- 1) Driver variables explaining the quantity (hectares) of deforestation (to be used in Sections 8.1.3.1 and 8.1.3.20, as appropriate), such as:

- a) Prices of agricultural products;
 - b) Costs of agricultural inputs;
 - c) Population density; and
 - d) Rural wages.
- 2) Driver variables explaining the location of deforestation, also called “predisposing factors” (de Jong 2007; to be used in Section 8.1.3.20), such as:
- a) Access to forests (such as vicinity to existing roads, railroads, navigable rivers and coastal lines);
 - b) Slope;
 - c) Proximity to markets;
 - d) Proximity to existing or industrial facilities (e.g., sawmills, pulp and paper mills, agricultural products processing facilities);
 - e) Proximity to forest edges;
 - f) Proximity to existing settlements;
 - g) Spatial variables indicating availability within the forest of land with good ecological conditions to expand agricultural activities, such as soil fertility and rainfall; and
 - h) Management category of the land (e.g., national park, indigenous reserve).

For each of these two sets of variables:

- 3) List the one to five key driver variables and provide any relevant source of information that provides evidence that each of the identified variables has been a driver of deforestation in the reference region during the historical reference period and is expected to be a driver of deforestation in the project area during the baseline validity period.
- 4) Briefly describe for each main agent group identified in Section 6.2.1 how the key driver variables have and will most likely impact each agent group’s decision to deforest.
- 5) For each identified key driver variable, provide information about its likely future development by providing any relevant source of information.
- 6) For each identified driver variable, briefly describe the project measures that will be implemented to address them,¹¹ where applicable.

6.2.3 Identification of Underlying Causes of Deforestation

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

- a) Land-use policies and their enforcement;
- b) Population pressure;

¹¹ This does not apply to spatial variables such as slope and elevation.

- c) Poverty and wealth;
 - d) War and other types of conflicts; and
 - e) Property regime.
- 1) List the one to five key underlying causes and cite any relevant source of information that provides evidence that the identified variables have been an underlying cause of deforestation during the historical reference period.
 - 2) Briefly describe how each key underlying cause has determined and will most likely determine the key drivers identified in Section 6.2.2 and the decisions of the main agent groups identified in Section 6.2.1.
 - 3) For each identified key underlying cause, provide information about its likely future development by citing any relevant source of information.
 - 4) For each identified underlying cause, describe the project measures that will be implemented to address them, where applicable.

6.2.4 Analysis of Chain of Events Leading to Deforestation

Based on the historical evidence collected, analyze the relationships between the main agent groups, key drivers and underlying causes and explain the sequence of events that has typically led to deforestation in the reference region during the historical reference period and will likely lead to future deforestation in the project area during the baseline validity period. Consult local experts, literature and other sources of information as necessary. Briefly summarize the results of this analysis in the PD.

6.2.5 Conclusion

The analysis of agents and drivers of deforestation must conclude with a statement about whether the evidence available about the most likely future deforestation trend in 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 are verifiable through statistical tests, desk 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.

Where multiple agents and drivers are present, the evidence obtained for each must be “conclusive” to allow a “conclusive” decision overall.

Where the evidence is conclusive, describe the most plausible baseline scenario and state whether the weight of the available evidence suggests that the overall trend in future baseline deforestation rates will be decreasing, approximately constant or increasing.

Use the outcome of the analysis to select the approach to project future deforestation quantity (Section 8.1.3).

Where the evidence is inconclusive and the historical deforestation trend is decreasing or roughly constant, additional analysis must be carried out such as more literature reviews, expert consultations and additional field surveys, until conclusive evidence on the most likely future deforestation trend is found. Where the historical deforestation trend is increasing and the evidence is inconclusive, the deforestation rate used in the projections must be the average historical rate (see Section 8.1.3.1). Alternatively, additional analysis may be carried out until conclusive evidence is found.

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

6.3 Revisiting Baseline Projections for Future Baseline Validity Period

Regardless of the approach chosen to establish them, baselines must be revisited over time because agents, drivers and underlying causes of deforestation change dynamically. Frequent and unpredictable updating of the baseline may create serious market uncertainties. Therefore, the baseline must be revisited as set out in the most recent version of the *VCS Standard*.

Where an applicable sub-national or national jurisdictional baseline becomes available, baselines may be reassessed earlier in accordance. Tasks involved in reassessing the baseline are:

- 1) Update information on agents, drivers and underlying causes of deforestation (Section 6.3.1).
- 2) Adjust the land use and land cover change component of the baseline (Section 6.3.2).
- 3) Adjust, as needed, the carbon component of the baseline (Section 6.3.3).

6.3.1 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.

- 1) Collect information that is relevant to understand deforestation agents, drivers and underlying causes.
- 2) Redo Step 2 (Section 6.2) at the beginning of each baseline validity period.
- 3) 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 baseline validity period.

6.3.2 Adjust the Land Use and Land Cover Change Component of the Baseline

6.3.2.1 Adjustment of Annual Areas of Baseline Deforestation

At the end of each baseline validity period, the projected annual areas of baseline deforestation for the reference region must be reassessed and eventually adjusted for the subsequent baseline validity period. The adjusted baseline rates must be submitted to a VVB.

Adjustments must be made using the processes described in this methodology and the data obtained from monitoring LU/LC changes in the reference region during the previous baseline validity 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. For this assessment, the historic reference period is extended to include the original reference period and all subsequent monitoring periods up to the beginning of the current monitoring period.

6.3.2.2 Adjustment of Projected Baseline Deforestation Location

Using the adjusted projections for annual areas of baseline deforestation and any improved spatial data for the creation of factor maps included in the spatial model, the location of projected baseline deforestation must be reassessed using the methods explained in this methodology.

All areas credited for avoided deforestation in past baseline validity periods must be excluded from the reassessed baseline projections as these areas must not be credited again. To perform this exclusion, use the map of “cumulative areas credited” that was updated in all previous verification events.

Note – where the boundary of the leakage belt area was assessed using Eq. (1) or any other spatial model, the boundary of the leakage belt must be reassessed at the end of each baseline validity period using the same methodological approaches as in the first period. This is required until monitoring of leakage becomes unnecessary.¹²

6.3.3 Adjustment of the Carbon Component of the Baseline

Adjusting the carbon component of the baseline is not necessary in most cases (see Sections 8.2.2.3 and 8.2.2.4 for more detailed guidance). However, improved carbon stock data are likely to become available over time and must be used when reassessing baseline projections. Methods to measure and estimate carbon stocks are described in Appendix 3.

¹² Monitoring of leakage becomes obsolete at the date on which another 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.

7 ADDITIONALITY

This methodology uses a project method for the demonstration of additionality. Additionality of the proposed AUD project activity must be demonstrated using the most recent version of *VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and other Land Use (AFOLU) Project Activities* and by following the additional guidance on investment analysis of the latest version of the *VCS Methodology Requirements*.

Project proponents must also demonstrate regulatory surplus in accordance with both the requirements on regulatory surplus set out in the latest version of the *VCS Standard* and the rules and methods to assess and demonstrate regulatory surplus described in the latest version of the *VCS Methodology Requirements*.

In UNFCCC non-Annex I countries, where regulatory surplus is justified by the lack of systematic law enforcement it must be demonstrated that enforcement of the law is out of the control of the project proponent and other entities involved in the project. Such lack of control may be demonstrated by the barriers identified in Step 3 of *VT0001*.

8 QUANTIFICATION OF ESTIMATED GHG EMISSION REDUCTIONS

8.1 Baseline Emissions

8.1.1 Analysis of Historical Land Use and Land Cover Change (Step 3)

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.

8.1.1.1 Collection of Suitable Data

Collect the data that will be used to analyze land use and land cover change in the reference region during the historical reference period. It is good practice to do this for at least three time points, about three to five years apart. For areas covered by intact forests, it is sufficient to collect data for one single date, which must be as close as possible to the project start date (≤ 2 years).

As a minimum requirement:

- 1) Collect medium resolution spatial data¹³ (from 30 m × 30 m up to a maximum of 100 m × 100 m resolution) from optical and non-optical sensor systems, such as but not limited to Landsat,¹⁴ Sentinel, SPOT and ASTER data covering the past 10 years.
- 2) Collect high resolution data from remote sensors (<5 × 5 m pixels) and/or from direct field observations for ground-truth validation of the posterior analysis. Describe the type of data, coordinates and sampling design used.
- 3) In Table 4, provide the following information about the data collected.

Table 4: Data Used for Historical LU/LC Change Analysis

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

Where already interpreted data of adequate spatial and temporal resolution are available, these may also be considered for posterior analysis, with some caution.¹⁵ Where data about historical LU/LC and/or LU/LC change are 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 align with IPCC classes and categories.

¹³ Guidance on the selection of data sources (such as remotely sensed data) may be found in Chapter 3A.2.4 of the *2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Vol. 4*, and in the latest version of the *GOFC-GOLD REDD Sourcebook*.

¹⁴ On 31 May 2003, the scan-line-corrector aboard Landsat 7 failed, producing horizontal zero-filled wedges in 22 percent 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).

¹⁵ Existing maps should be used with caution because they often do not report documentation, error estimates, whether they are specifically of the site or region in question or extracted from a national map and whether they were obtained by change detection techniques rather than by static map comparison.

8.1.1.2 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. An LU/LC class is a unique condition of land use or land cover for which:

- a) The boundary may be defined based on remotely sensed data and information, such as maps of vegetation, soil, elevation and management category, as defined by the project proponent to unambiguously define an LU/LC class; and
- b) Carbon stocks per hectare (t CO₂e/ha) are relatively homogeneous across the landscape. Carbon stocks must only be estimated for classes inside the project area, leakage belt and leakage management zones, as described in Step 6 (Section 8.1.5).

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

- 1) The minimum classes must be “Forest Land” and “Non-Forest Land.”
- 2) “Forest land” will in most cases encompass strata with different carbon stocks. Forest land must therefore be further stratified in forest classes with different average carbon densities.
- 3) “Non-Forest Land” may be further stratified in different non-forest classes. See the *2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories*, Vol. 4, Chapter 3, Section 3.2, for a description of potential non-forest land classes (cropland, grassland, wetlands, settlements and other land). Where appropriate to improve the accuracy of carbon stock estimates, classes in addition to those used in national GHG inventories may be defined.
- 4) The description of an LU/LC class must include criteria and thresholds that enable discrimination between classes. Select criteria and thresholds that allow a precise delineation of the LU/LC polygons of each class. Such criteria may include spectral definitions and other criteria such as elevation, slope, aspect, soil type, distance to roads¹⁶ and vegetation type. Where needed, in the “Description” column of Table 5, refer to more detailed descriptions in the methodological annex to be prepared according to Section 8.1.2.1.
- 5) For all forest classes present in the project area, specify whether logging for timber, fuel-wood collection or charcoal production occur in the baseline case. Where different combinations of forest class and baseline activities are present in the project area, define different classes for each combination, even where carbon densities are similar at the project start date.

¹⁶ 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 of the nearest road. In this example, an assumption is made that logging activities usually do not occur, or are of very low intensity, where the trees are more than 500 m from the nearest road). The use of indirect criteria must be briefly justified in the PD based on verifiable information, such as independent studies and literature. Using the definition of “degraded forest” from 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 must be monitored.

- 6) Where a forest class has predictably growing carbon density (i.e., is a secondary forest) and is located both in the project area and leakage belt, two different classes must be defined (see Section 8.1.5.1 for explanations).
- 7) In most cases, one single Land Use and Land Cover Map 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 density due to growth or degradation in the baseline case, a sequence of Land Use and Land Cover Maps representing the mosaic of forest classes in each future year may be generated.
- 8) 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 Appendix 1).
- 9) Any assumption of change in carbon densities in the baseline case must be documented using credible and verifiable sources of information, such as measurements in plots representing a chrono-sequence, published literature and other sources, as appropriate.
- 10) List the resulting final LU/LC classes in Table 5.

Table 5: List of All Land Use and Land Cover Classes Existing at the Project Start Date in the Reference Region

Class Identifier		Trend in Carbon Density	Presence In	Baseline Activity			Description (including criteria for unambiguous boundary definition)
<i>ID_{cl}</i>	Name			LG	FW	CP	
1							
2							
...							
<i>Cl</i>							

TABLE NOTES

<i>ID_{cl}</i>	Class identifier
Response options for Trend in Carbon Density	Note whether decreasing, constant or increasing. See Section 0 for a definition of carbon density
Response options for Presence In	RR = Reference region, LK = Leakage belt, LM = Leakage management zones, PA = Project area
LG	Logging
FW	Fuelwood collection

CP

Charcoal production

This methodology uses the notation icl ($= 1, 2, 3, \dots, Icl$) to indicate “initial” (pre-deforestation) classes, which are all forest classes; and fcl ($= 1, 2, 3, \dots, Fcl$) to indicate “final” (post-deforestation) classes. All classes (“initial” and “final”) must be listed in Table 6.

8.1.1.3 Definition of Land Use and Land Cover Change Categories

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

List the resulting LU/LC change categories in Table 6 and Table 7.

Table 6: Potential Land Use and Land Cover Change Matrix

ID_{cl}		Initial LU/LC class			
		$i1$	$i2$	$i\dots$	I_n
Final LU/LC class	$f1$	$i1/f1$	$i2/f1$	$i\dots/f1$	$I_n/F1$
	$f2$	$i1/f2$	$i2/f2$	$i\dots/f2$	$I_n/F2$
	$f\dots$	$i1/f\dots$	$i2/f\dots$	$i\dots/f3$	$I_n/F\dots$
	F_n	$I1/F_n$	$I2/F_n$	$I\dots/F_n$	I_n/F_n

Table 7: List of Land Use and Land Cover Change Categories

ID_{ct}	Name	Trend in Carbon Density	Presence in	Activity in Baseline Case			Name	Trend in Carbon Density	Presence in	Activity in Project Case		
				LG	FW	CP				LG	FW	CP
$i1/f1$												
$i1/f2$												
$i1/f\dots$												
$i2/f1$												

ID _{ct}	Name	Trend in Carbon Density	Presence in	Activity in Baseline Case			Name	Trend in Carbon Density	Presence in	Activity in Project Case		
				LG	FW	CP				LG	FW	CP
i2/f2												
i2/f...												
i.../f1												
i.../f2												
i.../f...												

8.1.1.4 Analysis of Historical Land-Use and Land-Cover Change

Using the data collected in Section 8.1.1.1, divide the reference region in polygons¹⁷ representing the LU/LC classes and LU/LC change categories defined in Sections 8.1.1.2 and 8.1.1.3. In 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 where the classes and categories are well described in these maps; the same classes and categories may be used in Sections 8.1.1.2 and 8.1.1.3.

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, LU/LC change analysis involves pre-processing, interpretation and classification and post-processing.

Pre-processing

Pre-processing typically includes:

- 1) Geometric corrections to ensure that images in a time series properly overlay each other and other GIS maps used in the analysis (i.e., for post-classification stratification). The average location error between two images should be less than one pixel.
- 2) Cloud and shadow removal using additional data (e.g., radar, aerial photographs, field-surveys)

¹⁷ Raster or grid data formats are allowed.

- 3) Radiometric corrections may be necessary (depending on the change-detection technique used) to ensure that similar objects have the same spectral response across multi-temporal datasets.
- 4) Reduction of haze, as needed

See the most recent version of the GOF-C-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.

Interpretation and Classification

Two main categories of change detection exist and may be used (see *2019 Refinements to the IPCC 2006 Guidelines*, Chapter 3A.2.4):

- 1) Post-classification change detection: 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 LU/LC classes.
- 2) Pre-classification change detection: These are more sophisticated approaches to LU/LC change detection that require more data pre-processing (i.e., radiometric corrections). The basic approach is to compare by statistical methods the ground spectral response using two datasets acquired at different dates to detect locations where a change has occurred. Different patterns of spectral change are allocated 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 datasets, this methodology does not prescribe any specific method.

- Automated classification methods are preferred because the interpretation is more efficient and repeatable than 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. Image segmentation followed by supervised object classification may be effective.
- Minimum mapping unit size must not be more than one hectare irrespective of forest definition.
- See the most recent version of the GOF-C-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.

Post-processing

Post-processing includes the use of non-spectral data to further stratify LU/LC classes with heterogeneous carbon density into LU/LC classes with homogenous carbon density. Post-classification stratification may be performed efficiently using GIS.

LiDAR and other remote sensing technologies, when combined with field-surveys, may be used under this methodology. Some forest types (e.g., broadleaved forest, coniferous forests, mangroves) may be accurately discriminated using remotely sensed data only.

For LU/LC classes where further stratification using remote sensing techniques is not possible and the classes are likely to encompass a broad range of carbon density classes, further stratification should be based on any of the following:

- 1) Biophysical criteria (e.g., climate or ecological zone, soil and vegetation type, elevation, rainfall, slope, aspect);¹⁸
- 2) Disturbance indicators (e.g., vicinity to roads; forestry concession areas);
- 3) Age (for plantations and secondary forests);
- 4) Land management categories (e.g., protected forest, indigenous reserve); and/or
- 5) Other criteria relevant to distinguish carbon density classes.

See the most recent version of the GOFC-GOLD sourcebook for REDD and IPCC (2006) Volume 4 for further guidance on stratification. The criteria finally used should be reported transparently in the PD and referenced to in Table 5. Some iteration between Sections 8.1.1.2, 8.1.1.3 and this section may be necessary.

Duly record all post-processing steps for later reporting.

At the end of Step 3 (Section 8.1.1), the following products must be prepared for the reference region (including the project area):

- 1) Forest cover maps showing “forest” land and “non-forest” land at different dates over the historical reference period. Forest cover maps must be developed for a minimum of three distinct years representing the beginning, midpoint and end of the historical reference period. All of the following apply to the project’s forest cover maps:
 - a) Intervals between forest cover maps should be as similar in duration as data availability allows;
 - b) To allow for subdivision of the historical reference period into a calibration period and a confirmation period, an odd number of forest cover maps must be used; and
 - c) Good practice in remote sensing analysis must be followed.
- 2) A land-use and land-cover map for at least the most recent date (± 2 years from the project start date) depicting the LU/LC classes defined in Section 8.1.1.2.

¹⁸ IPCC 2006 Guidelines for National GHG Inventories provides default climate and soil classification schemes in Annex 3A.5 and guidance on stratifying LU/LC areas in Section 3.3.2.

- 3) A deforestation map for each sub-period analyzed. These maps are generated from successive forest cover maps and must include the following land cover change categories: forest remaining forest, forest to non-forest (deforestation), non-forest remaining non-forest, and non-forest to forest. Where possible, the forest to non-forest category must be separated into planned and unplanned deforestation to enable exclusion of planned deforestation from the reference region as required in Section 5.1.1. Where relevant, deforestation maps must identify areas of mangrove and peat forest.
- 4) A land use and land cover change map for at least the most recent period analyzed (three to five years) depicting the LU/LC change categories defined in Section 8.1.1.3. In most cases, this map will be prepared by combining the Deforestation Map of the most recent period (three to five years) with the most recent Land Use and Land Cover Map.
- 5) A land-use and land-cover change matrix for at least the most recent period analyzed, derived from the LU/LC change map or the Deforestation Map and the post-deforestation land-use data mentioned above, showing activity data for each LU/LC change category. See Appendix 5 for an example of an LU/LC change matrix.

8.1.1.5 Map Accuracy Assessment

A verifiable accuracy assessment of the maps produced in the previous step is necessary to produce a credible estimate of the historical deforestation area.¹⁹ The requirements for accuracy assessment are:

- 1) The accuracy must be estimated on a class-by-class (LU/LC map) and, where applicable, category-by-category (LU/LC change map) basis, respectively.
- 2) Accuracy must be assessed based on visual sampling of high-resolution imagery as a reference. High-resolution (≤ 5 -meter resolution) imagery must be used where available. 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 Section 8.1.5.1) may 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 categories. Based on the error matrix (also called confusion matrix), a number of accuracy indices may be derived (see e.g., Congalton (1991) and Pontius (2000)).
- 3) The minimum overall accuracy of the forest cover map must be 90 percent.
- 4) 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, must be 80 percent. Where the classification of a class or category is lower than 80 percent:

¹⁹ See Chapter 5 of *IPCC 2003 GPG*, Chapter 3A.2.4 of *IPCC 2006 Guidelines* and the most recent version of the *GFOC-GOLD Sourcebook on REDD* for guidance on map accuracy assessment.

- a) Consider merging the class/category with other classes/categories;²⁰ or
 - b) Exclude from the forest cover map 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 forest cover map.
- 5) 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.
 - 6) Where ground-truthing data are not available for time periods in the past, the accuracy may be assessed only at the most recent date for which it is possible to collect ground-truthing data.

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

8.1.2 Estimation of Land Cover and Land Cover Change Areas

Estimation of land cover and land cover change areas must not be derived from uncorrected pixel counts of land cover or land cover change maps. A bias correction must be applied to the area estimates based on the accuracy assessment and using standard best practice methods (for example, GFOI *Methods and Guidance* document, v2.0, page 136, Box 24 or v3.0, page 185, Box 32). The estimation of land cover and land cover change areas results in mean area estimates, each including an uncertainty estimate representing sampling error. as a two-sided 90 percent confidence interval. The uncertainty estimates must be reported in hectares and as a percentage of the area estimate.

The bias-corrected estimate of the land cover change area must be conservatively discounted to reduce the risk of overestimation:

$$\text{Conservatively discounted unplanned deforestation area} = \text{bias-corrected area estimate} \times (1 - \text{discount factor})$$

The discount factors must be based on the uncertainty, $U\%$, of the estimate to be discounted (i.e., the half-width of the two-sided 90 percent confidence interval as a percentage of the mean estimate). The discount factors are given by the following:

- 1) Where the uncertainty is less than or equal to 10 percent of the mean, the discount factor is zero percent.
- 2) The uncertainty must not exceed 20 percent.

²⁰ The tradeoff of merging classes or categories is that carbon estimates will be subject to a higher degree of variability.

- 3) Where the uncertainty is more than 10 percent and less than 20 percent of the mean:

$$DF = (U\%/t_{\alpha=10\%}) \times t_{\alpha=66.67}$$

Where:

DF	=	Discount factor (%)
$U\%$	=	Percentage uncertainty of the area of the reference region classified as unplanned deforestation through plot sampling (i.e., the half-width of the 90 percent confidence interval as a percentage of the mean estimate) (%)
t	=	Values from the t distribution ($t_{\alpha=10\%}$ is the t value for the two-sided 90 percent confidence interval, approximately 1.6449; $t_{\alpha=66.67\%}$ is the t value for a one-sided 66.67 percent confidence interval, approximately 0.4307) (dimensionless)

8.1.2.1 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 (baseline validity 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 may be used where the images based on interpretation of the new data overlap the images based on interpretation of the old data by at least one year and the images cross calibrate to acceptable levels based on commonly used methods in the remote sensing community.

The risk of introducing artifacts from method change must be minimized to achieve a consistent time series. For this reason, the detailed methodological procedures used in pre-processing, classification, post-classification processing and accuracy assessment of the remotely sensed data must be carefully documented in an annex to the PD. This annex must be public or sufficient information must be provided in the PD to enable an external reviewer to assess the quality of the data. In particular, the following information must be documented:

- 1) Data sources and pre-processing:
 - a) Type, resolution, source, and acquisition date of the remotely sensed data (and other data) used
 - b) Geometric, radiometric and other corrections performed, where relevant
 - c) Spectral bands and indexes used (such as NDVI)
 - d) Projection and parameters used for geo-referencing the images
 - e) Error estimate of the geometric correction
 - f) Software and software version used to perform pre-processing tasks
- 2) Data classification and post-processing:
 - a) Definition of the LU/LC classes and LU/LC change categories

- b) Classification approach and classification algorithms
 - c) Coordinates and description of the ground-truthing data collected for training purposes
 - d) Ancillary data used in the classification, where relevant
 - e) Software and software version used to perform the classification
 - f) Additional spatial data and analysis used for post-classification analysis, including class subdivisions using non-spectral criteria, where relevant
- 3) Classification accuracy assessment:
- a) Accuracy assessment technique used
 - b) Coordinates and description of the ground-truth data collected for classification accuracy assessment
 - c) Post-processing decisions made based on the preliminary classification accuracy assessment, where relevant
 - d) Final classification accuracy assessment

8.1.3 Projection of Future Deforestation (Step 4)

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

8.1.3.1 Projection of the Quantity of Future Deforestation

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

Where appropriate, the reference region may be stratified according to the findings of Section 8.1.1 and different deforestation rates estimated for each stratum. Where 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.

Table 8: Stratification of the Reference Region

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

TABLE NOTES

Area at year	Where the boundary of the strata is dynamic, explain the rationale and provide the estimated annual area of each stratum.
--------------	---

A projected deforestation rate must be determined by the project proponent taking into account possible future changes in 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 two analytical sub-steps: selection of the baseline approach and quantitative projection of future deforestation.

Selection of the Baseline Approach

To project future deforestation, two baseline approaches are available:

- **Historical average approach:** 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 in the reference region or, where appropriate, in different strata of the reference region.
- **Time function approach:** With this approach, the rate of baseline deforestation is estimated by extrapolating the historical trend observed in the reference region (or its strata) as a function of time using a simple linear regression model. This approach may be applied when a 10-year annual deforestation time series is available. The regression model must be statistically significant ($p \leq 0.05$), have an $r^2 \geq 0.75$ and be free from bias (demonstrated through selection of the fit with the lowest residuals). Standard equations for estimating uncertainties in regression forecasting should be applied, and the *VCS Methodology Requirements* guidance on uncertainty discounting must be used. Where the regression model does not meet these statistical requirements, the historical average must be used instead.

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

- 1) Where deforestation rates measured over the historical reference period in the reference region (or a stratum of it) do not reveal any trend (decreasing, constant or increasing deforestation) and:
 - a) No conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates – then do additional assessments under Step 2 (Section 6.2), such as more literature reviews, expert consultations and additional field surveys until conclusive evidence is found.

- b) Conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates – then use the historical average approach.
 - 2) Where deforestation rates measured over the different historical sub-periods in the reference region (or a stratum of it) reveal a clear trend, and this trend is:
 - a) Decreasing and:
 - i) Conclusive evidence emerges from analyzing agents and drivers explaining the decreasing trend and making it likely to continue – then use the time function approach.
 - ii) No conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend – then do additional assessments under Step 3 (Section 8.1.1), such as more literature reviews, expert consultations and additional field surveys, until finding conclusive evidence
 - b) Relatively constant and:
 - i) Conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend and making it likely that this trend will continue – then use the historical average approach.
 - ii) No conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend – then do additional assessments under Step 3 (Section 8.1.1), such as more literature reviews, expert consultations and additional field surveys, until conclusive evidence is found.
 - c) Increasing and:
 - i) Conclusive evidence emerges from analyzing agents and drivers explaining the increased trend and making it likely to continue – then use the time function approach.
 - ii) No conclusive evidence emerges from analyzing agents and drivers explaining the increasing trend – then use the historical average approach.

Quantitative Projection of Future Deforestation

The 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 (Section 8.1.3.20), and finally, to determine the annual areas and location of deforestation in the project area and leakage belt.

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

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

Historical average

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

$$ABSLRR_{i,t} = ARR_{i,t-1} \times RBSLRR_{i,t}/100 \quad (3)$$

Where:

$ABSLRR_{i,t}$	=	Annual area of baseline deforestation in stratum i within the reference region at year t (ha/yr)
$ARR_{i,t-1}$	=	Area with forest cover in stratum i in the reference region at year $t - 1$ (ha)
$RBSLRR_{i,t}$	=	Deforestation rate ²¹ 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)
i	=	1, 2, 3, ..., I_{RR} , a stratum within the reference region (dimensionless)

Time function

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

$$ABSLRR_{i,t} = a + b \times t \quad (4)$$

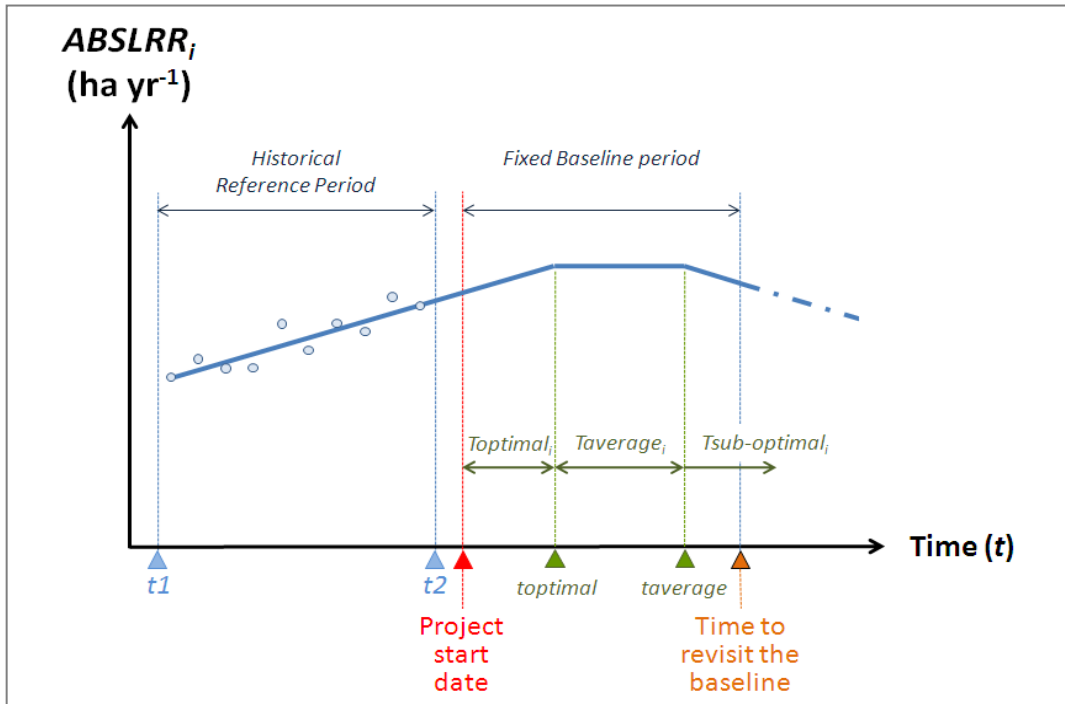
Where:

$ABSLRR_{i,t}$	=	Annual area of baseline deforestation in stratum i within the reference region at year t (ha/yr)
a	=	Estimated intercept of the regression line (ha/yr)
b	=	Estimated coefficient of the time variable (or slope of the linear regression) (ha/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)

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 Figure 5 below.

²¹ See Puyravaud, J. P. (2003). Standardizing the calculation of the annual rate of deforestation. *Forest Ecology and Management*, 177(1-3), 593-596. [https://doi.org/10.1016/S0378-1127\(02\)00335-3](https://doi.org/10.1016/S0378-1127(02)00335-3)

Figure 5: Time Function for Modeling $ABSLRR_i$



It must be demonstrated to the VVB at validation that the model i complies with statistical good practice.

If $ABSLRR_{i,t}$ decreases as a function of time, then $Toptimal_i$ is the period of time during which $ABSLRR_{i,t}$ yields a positive value. After that period of time, $ABSLRR_{i,t} = 0$.

If $ABSLRR_{i,t}$ increases as a function of time, then $Toptimal_i$ is the period of time between $t = 1$ and $t = toptimal_i$, the latter being the year at which the following condition is satisfied:

$$A_{optimal_i} = \sum_{t=1}^{toptimal_i} ABSLRR_{i,t} \quad (5)$$

Where:

- $A_{optimal_i}$ = Area of "optimal" forest land suitable for conversion to non-forest land within stratum i (see below) (ha)
- $ABSLRR_{i,t}$ = Annual area of baseline deforestation in stratum i within the reference region in year t (ha/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)
- $toptimal_i$ = Year at which $Toptimal_i$ ends (yr)

If: $Toptimal_i \geq$ project crediting period, then $ABSLRR_{i,t}$ calculated with Eq. (4) is applicable during the entire project crediting period.

If: $Toptimal_i < \text{project crediting period}$, then $ABSLRR_{i,t}$ calculated with Eq. (4) is applicable only to the first $Toptimal_i$ years. For the following $Taverage_i$ years use value of $ABSLRR_{i,t}$ calculated for the year $t = Toptimal_i$: $Taverage_i$ 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:

$$Aaverage_i = \sum_{t=toptimal_i}^{taverage_i} ABSLRR_{i,t} \quad (6)$$

Where:

$Aaverage_i$	=	Area of “average” forest land suitable for conversion to non-forest land within stratum i (see below) (ha)
$ABSLRR_{i,t}$	=	Annual area of baseline deforestation in stratum i within the reference region at year t (ha/yr)
t	=	1, 2, 3, ..., T , a year of the proposed project crediting period (dimensionless)
i	=	1, 2, 3, ..., l_{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: $Toptimal_i + Taverage_i \geq \text{project crediting period}$, then $ABSLRR_{i,t}$ calculated for the year $t = toptimal_i$ is applicable during the period of time between $t = toptimal_i$ and $t = taverage_i$

If: $Toptimal_i + Taverage_i < \text{project crediting period}$, then $ABSLRR_{i,t}$ calculated for the year $t = toptimal_i$ is applicable only to the first $Taverage_i$ years following year $toptimal_i$. For the following 20 years, assume a linear decrease of $ABSLRR_{i,t}$ down to zero hectares per year in $t = taverage + 20$

$$ABSLRR_{i,t} = ABSLRR_{taverage,i} (1 - 1/20 \times (t - taverage_i)) \quad (7)$$

Where:

$ABSLRR_{i,t}$	=	Annual area of baseline deforestation in stratum i within the reference region in year t (ha/yr)
$ABSLRR_{taverage,i}$	=	Annual area of baseline deforestation in stratum i within the reference region at year $taverage_i$ (ha/yr)
$taverage_i$	=	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, ..., l_{RR} , a stratum within the reference region (dimensionless)

Note – After $taverage_i + 20$ years, $ABSLRR_{i,t}$ is zero hectares per year in all cases.

Calculation of $Aoptimal_i$ and $Aaverage_i$ under the time function approach

$Aoptimal_i$ (area of “optimal” forest land suitable for conversion to non-forest land within stratum i) and $Aaverage_i$ (area of “average” forest land suitable for conversion to non-forest land within

stratum i) must be determined to avoid non-conservative projections of baseline deforestation when “increasing deforestation” is projected under the time function approach. Deforestation may increase in the future only 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 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) Identify land-use constraints: Identify the appropriate biophysical constraints (e.g., soil, climate, elevation, slope) and appropriate socio-economic constraints (e.g., mobility, land-use rights, areas with presence of conflicts and crime) that limit the geographical area where deforestation agents may 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 the agents have deforested historically (e.g., range of slopes, types of soil, minimum/maximum rainfall, elevation range; relevant to determine the range in which the main types of crops and livestock are able to survive). Use spatial data, literature, surveys and/or participatory rural appraisal as appropriate.
- 2) Estimate the remaining forest area that may be converted to non-forest land: Using the constraints identified above, develop a Maximum Potential Deforestation Map, which maps the area currently covered by forest that is potentially available for the further expansion of non-forest uses in the reference region.
- 3) Stratify the Maximum Potential Deforestation Map into broad suitability classes: Considering the constraints identified above, define criteria and thresholds that delineate “optimal,” “average” and “sub-optimal” conditions for each of the main land uses implemented by the main agent groups (e.g., by defining ranges of slope, rainfall or types of soils, or ranges of deforestation risks according to the deforestation risk map created for the spatial model (see Section 8.1.3.20). 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. Where available use existing maps from other sources.
- 4) $A_{optimal_i}$ is the area of the “optimal” suitability class within stratum i , and $A_{average_i}$ is the area of the “average” suitability class within stratum i .

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

Location analysis of future deforestation within the reference region (Section 8.1.3.2) is required to determine the annual areas of deforestation within the project area and leakage belt. 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.

Quantitative Projection of Future Deforestation Section Summary

Present the results of the previous assessments in Table 10 and Table 11. Do this at least for the baseline validity period and, optionally, for the entire project crediting period.

Table 9: Annual Areas of Baseline Deforestation in the Reference Region

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

Table 10: Annual Areas of Baseline Deforestation in the Project Area ($ABSLPA$)

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

Table 11: Annual Areas of Baseline Deforestation in the Leakage Belt (ABSLLK)

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

8.1.3.2 Projection of the Location of Future Deforestation

Annual areas of baseline deforestation in the reference region are estimated in Section 8.1.3.1. This section 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.

Analysis 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 deforestation agents. 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 may 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 may be represented in a map (or Factor Map) and overlaid to a map showing historical deforestation using a 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 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 built nearby or when areas are deforested nearby).

Several models/software are available and may be used to perform these tasks in slightly different ways, such as Geomod, TerrSet, Dinamica EGO, CLUE and Land Change Modeler. The model/software used must be peer-reviewed and must be demonstrated at validation to be consistent with the methodology.

Preparation of Factor Maps

Based on the analysis of Step 3 (Section 8.1.1) and Section 8.1.3.1, 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 Spatial Features of each variable (i.e., the shape files representing the point, lines or polygon features or the raster files representing surface features). When significant spatial variables are outside of the reference region²², the spatial data must be collected for a larger area than the reference region not to bias the model.

Some models will require production of Distance Maps 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). Where the model/software allows working with dynamic Distance Maps (i.e., the software is able to calculate new Distance Maps at each time step), these should be used. For simplicity, these maps are called “Factor Maps.” 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 may 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 construction timeline. For 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). Appropriate evidence includes approved plans and budgets for construction, signed construction contracts or an open bidding process with approved budgets and finance. Where 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.

²² For example, the reference region may include deforestation alongside an highway while the highway itself is outside of the reference region boundary.

In case of unplanned infrastructure (e.g., secondary roads), provide evidence that the unplanned infrastructure will actually develop (e.g., based on historical developments). Specifically, from a wall-to-wall assessment (or at least five randomly sampled observations in the reference region) or from literature sources relevant to the reference region, estimate the average annual length²³ of new unplanned infrastructure per square kilometer²⁴ that was constructed during the historical reference period. Alternatively, determine the historical rate of change in those variables for which there are good projections (e.g., km of new unplanned infrastructure as related to population). To avoid projecting unplanned infrastructure into areas where geographic and socio-economic conditions are unsuitable for infrastructure development (e.g., areas with steep slopes, swampy soils, low opportunity costs), develop a map representing a proxy of 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:

- 1) Using historical data, expert opinion, participatory rural appraisal, literature and/or other verifiable sources of information, list all relevant criteria that facilitate (at least one criterion) or constrain (at least one criterion) the development of new unplanned infrastructure.
- 2) For each criterion, generate a map using a GIS.
- 3) Using multi-criteria analysis, determine the most likely rate of unplanned infrastructure development (e.g., km/km²/yr or a similar indicator) for different sectors (suitability classes or gradients) within the reference region.

Projections of unplanned infrastructure development, particularly in forested areas, must be conservative.

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

- a) 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). In a table, describe the rule used to build classes and the deforestation likelihood assigned to each distance class.²⁵ The deforestation likelihood is estimated

²³ Other parameters relevant for modeling the construction of secondary roads may also be measured in this analysis, such as distance between roads and number of destinations per year. Parameters to be assessed are dependent on the modeling approach used to project the development of the road network and are therefore not further specified here.

²⁴ Or per kilometer of official new road constructed, or per other landscape features that may be mapped (such as new industrial facilities, settlements, mining concessions), as appropriate

²⁵ Classes of continuous variables should be 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” may not have a linear relationship with deforestation risk: a forest located at 50 km from the nearest road may be subject to the same deforestation risk as 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 may be obtained by analyzing the distribution of sample points taken from historically deforested areas.

as the percentage of pixels that were deforested during the period of analysis (i.e., the historical reference period).

- b) Heuristic approach: Define “value functions” representing the likelihood of deforestation as a function of distance from point features (e.g., sawmills) 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.

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 (land-use and land-cover change maps produced with Step 2 (Section 6.1) and to use regression²⁶ to define the probability of deforestation as a function of “distance.”

The empirical approach is 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.

Preparation of Deforestation Risk Maps

A Risk Map shows at each pixel location l the risk (or “probability”) of deforestation on a numerical scale (e.g., 0 = minimum risk; 255 = maximum risk).

Models use different techniques to produce risk maps and algorithms vary among 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 validation.

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

A list of Factor Maps, including the maps used to produce them and the corresponding sources must be presented in the PD (Table 12) together with a flow-chart diagram illustrating how the Risk Map is generated.

²⁶ For example logistic regression

Table 12: 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		

Selection of the Most Accurate Deforestation Risk Map

The quality of the model output must be confirmed (generally referred to as model validation in the modeling community) in order 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 validation, referred to here as calibration and confirmation (to avoid confusion 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) is preferred where recent deforestation trends differ from those in the more distant past.

- 1) Where two or more historical sub-periods show a similar deforestation trend, data from the most recent period may be used as the “confirmation” dataset, and those from the previous period as the “calibration” dataset.
Using only the data from the calibration period, prepare for each Risk Map a Prediction Map of 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 Risk Map that was used to produce it. Prepare the final Risk Map using the data from the calibration and the confirmation period.
- 2) Where only one historical sub-period is representative of what is likely to happen in the future, divide the reference region into tiles and randomly select half of the tiles for the calibration dataset 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, TerrSet, Land Change Modeler and Dinamica EGO, include in the software package appropriate assessment techniques, which may

be used under this methodology. Techniques that assess the accuracy of the prediction at the polygon level are preferred, such as the predicted compared to observed quantity of total deforestation within the project area.

One assessment technique that may be used is the “Figure of Merit” (*FOM*) that confirms model prediction in a statistical manner (Pontius et al., 2008; Pontius et al., 2007).²⁷

The *FOM* is a ratio of the intersection of the observed change (change between the reference maps at 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 (Eq. (9)). 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 change. The highest *FOM* value must be used as the criterion for selecting the most accurate Deforestation Risk Map to be used for predicting future deforestation.

$$FOM = B / (A + B + C) \quad (9)$$

Where:

<i>FOM</i>	=	Figure of Merit (dimensionless)
<i>A</i>	=	Area in which observed change is incorrectly predicted as persistence (ha)
<i>B</i>	=	Area in which observed change is correctly predicted as change (ha)
<i>C</i>	=	Area in which observed persistence is incorrectly predicted as change (ha)

The minimum threshold for the best fit as measured by the *FOM* must be defined by the net observed change in the reference region for the calibration period of the model. Net observed change must be calculated as the total area of change being modeled in the reference region during the calibration period as a percentage of the total area of the reference region. The *FOM* value must be equivalent to or larger than the net observed change value. If the *FOM* value is below this threshold, the project proponent must demonstrate that at least three models have been tested, and that the one with the best *FOM* is used.

Mapping the Location 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:

- 1) In the most accurate Deforestation Risk Map, select the pixels with the highest deforestation probability. Add the area of these pixels until their total area is equal to

²⁷ Pontius Jr, R. G., Boersma, W., Castella, J. C., Clarke, K., de Nijs, T., Dietzel, C., Duan, Z., Fotsing, E., Goldstein, N., Kok K., Koomen, E., Lippitt, C. D., McConnell, W., Mohd Sood, A., Pijanowski, B., Pithadia, S., Sweeney, S., Trung, T. N., Veldkamp, A. T., & Verburg, P. H. (2008). Comparing input, output, and validation maps for several models of land change. *Annals of Regional Science*, 42(1), 11–37. <https://doi.org/10.1007/s00168-007-0138-2> Pontius Jr, R. G., Walker, R., Yao-Kumah, R., Arima, E., Aldrich, S., Caldas, M., & Vergara, D. (2007). Accuracy assessment for a simulation model of Amazonian deforestation. *Annals of the Association of American Geographers*, 97(4), 677–695. <https://doi.org/10.1111/j.1467-8306.2007.00577.x>

the area expected to be deforested in the reference region in the first year of the project according to Table 9. The result is the Map of Baseline Deforestation for year 1.

- 2) 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 baseline validity period and, optionally, for the entire project crediting period.
- 3) Add all yearly baseline deforestation maps in one single map showing the expected Baseline Deforestation for the baseline validity 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 may 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 polygon corresponding to the project area. After this step, Table 10 may be completed. To obtain the annual areas of baseline deforestation within leakage belt, combine the annual maps of baseline deforestation for the reference region with a map depicting only the polygon corresponding to the leakage belt, then complete Table 11.

8.1.4 Definition of Land Use and Land Cover Change Component of the Baseline (Step 5)

The goal of this step is to calculate activity data²⁸ of the initial forest classes (*icl*) that will be deforested and activity data of the post-deforestation classes (*fcI*) that will replace them in the baseline case.

After Step 4 (Section 8.1.3), the area and location of future deforestation are both known and pre-deforestation carbon stocks may be determined by matching the predicted location of deforestation with the location of forest classes with known carbon stocks.

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

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

8.1.4.1 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 (Section 6.2) to produce a set of maps showing for each forest class the polygons that would

²⁸ Activity data is measured in hectares per year.

be deforested each year in the 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 13 (for the reference region),²⁹ Table 14 (for the project area) and Table 15 (for the leakage belt). Do this at least for the baseline validity 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 be produced in Step 2 (Section 6.2). 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 be generated in Step 2 (Section 6.2), in which case these must be used in this step.

Table 13: Annual Areas Deforested Per Forest Class *icl* Within the Reference Region in the Baseline Case (Baseline Activity Data Per Forest Class)

Area deforested per forest class <i>icl</i> within the reference region					Total baseline deforestation in the reference region	
<i>ID_{icl}</i> >	1	2	...	<i>icl</i>	<i>ABSLRR_t</i>	<i>ABSLRR</i>
Name >					annual	cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
<i>T</i>						

²⁹ The table summarizing the annual areas deforested per forest class *icl* within the reference region in the baseline case is optional.

Table 14: 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 <i>icl</i> within the project area					Total baseline deforestation in the project area	
<i>ID_{icl}</i> >	1	2	...	<i>icl</i>	<i>ABSLPA_t</i>	<i>ABSLPA</i>
Name >					annual	cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
<i>T</i>						

Table 15: Annual Areas Deforested Per Forest Class *icl* Within the Leakage Belt in the Baseline Case (Baseline Activity Data Per Forest Class)

Area deforested per forest class <i>icl</i> within the leakage belt					Total baseline deforestation in the leakage belt	
<i>ID_{icl}</i> >	1	2	...	<i>icl</i>	<i>ABSLLK_t</i>	<i>ABSLLK</i>
Name >					annual	cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
<i>T</i>						

8.1.4.2 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: historical LU/LC change and modeling.

Method 1: Historical LU/LC Change

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

Divide the reference region (or at least the area encompassing the project area, leakage belt and leakage management zones) into Z zones (at least one zone), each representing different combinations of possible post-deforestation land uses, taking into account the historical location of post-deforestation LU/LC classes and the requirements (climate, soil, economic factors) for each different class to be established in a given zone in the baseline case.

Where more than one zone exists, include in the PD a map showing the location of these zones (Map of Zones of Post-Deforestation Land Uses) and provide a brief explanation of the zoning rationale. In Table 16, report the area of each zone and the areas of each post-deforestation LU/LC class present in each zone (based on the maps and data produced in Step 2, Section 6.2).

Table 16: Zones of the Reference Region³⁰ Encompassing Different Combinations of Potential Post-Deforestation LU/LC Classes

Zone		Name:		Name:		Name:		Total of all other LU/LC classes present in zone		Total area of zone	
		F1		F2		F50					
		ID_{fcl}	1	ID_{fcl}	2	ID_{fcl}	F_{cl}				
		Area	% of Zone	Area	% of Zone	Area	% of Zone	Area	% of Zone	Area	% of Zone
iD_z	Name	ha	%	ha	%	ha	%	ha	%	ha	%
1	Zone 1		0.0		0.0		0.0		0.0	-	0.0
2	Zone 2		0.0		0.0		0.0		0.0		0.0
...	Zone ...		0.0		0.0		0.0		0.0		0.0

³⁰ A smaller area than the reference region may be considered where it contains at least the project area, the leakage belt and the leakage management zones.

Zone		Name:		Name:		Name:		Total of all other LU/LC classes present in zone		Total area of zone	
		F1		F2		F50					
		ID_{fcl}	1	ID_{fcl}	2	ID_{fcl}	F_{cl}				
		Area	% of Zone	Area	% of Zone	Area	% of Zone	Area	% of Zone	Area	% of Zone
ID_z	Name	ha	%	ha	%	ha	%	ha	%	ha	%
Z	Zone Z		0.0		0.0		0.0		0.0		0.0
Total area of each class f_{cl}		-	0.0	-	0.0	-	0.0	-	0.0	-	0.0

Calculate the area projected to be deforested in each zone and report the result in Table 18 (for the project area) and Table 19 (for the leakage belt). Do this at least for the baseline validity period and, optionally, for the entire project crediting period. Doing the same for the reference region (Table 17) is optional.

Table 17: Annual Areas Deforested in Each Zone Within the Reference Region in the Baseline Case (Baseline Activity Data Per Zone)

$ID_z >$	1	2	...	Z	Total baseline deforestation in the reference region	
	Name > Zone 1	Zone 2	Zone 3	Zone Z	$ABSLRR_t$	$ABSLRR$
Project year t	ha	ha	ha		ha	ha
0						
1						
2						
3						
T						

Table 18: Annual Areas Deforested in Each Zone Within the Project Area in the Baseline Case (Baseline Activity Data Zone)

Area established after deforestation per zone within the project area					Total baseline deforestation in the project area	
$iD_z >$	1	2	...	Z		
Name >	Zone 1	Zone 2	Zone 3	Zone Z	$ABSLPA_t$	$ABSLPA$
Project year t	ha	ha	ha		ha/yr	ha
0						
1						
2						
3						
T						

Table 19: Annual Areas Deforested in Each Zone Within the Leakage Belt in the Baseline Case (Baseline Activity Data Per Zone)

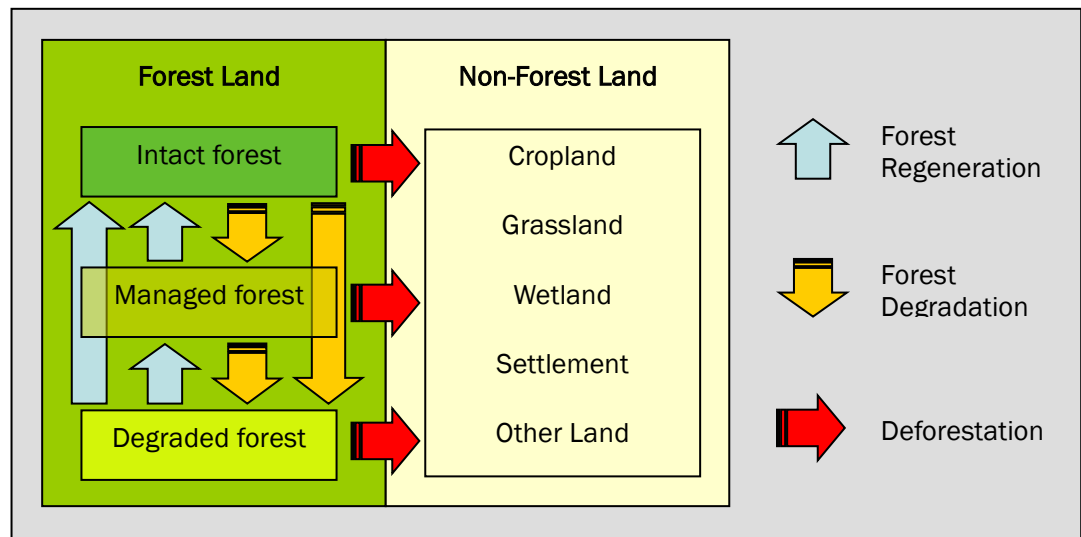
$iD_z >$	1	2	...	Z	Total baseline deforestation in the leakage belt	
Name >	Zone 1	Zone 2	Zone 3	Zone Z	$ABSLK_t$	$ABSLK$
Project year t	ha	ha	ha		ha/yr	ha
0						
1						
2						
3						
T						

Method 2: Modeling

The future spatial distribution of post-deforestation LU/LC classes is determined using a spatial model. Two modeling techniques may be used:

- 1) Projection of LU/LC change categories: Some deforestation modeling tools may be used to project several LU/LC change categories simultaneously, instead of just the broad category of “deforestation” (see Figure 6).

Figure 6: Broad Categories of Land Use and Land Cover Change



In such cases, non-forest classes are determined by each projected category of change. Methods discussed in Section 8.1.3.20 must be used to select the most accurate prediction map.

- 2) Suitability modeling:
 - a) Factors that determine the suitability of each main post-deforestation LU/LC class, such as soil type, elevation and slope (as selected and justified by the project proponent) must be identified.
 - b) The suitability of the spatial location of each post-deforestation LU/LC class is determined using multi-criteria analysis. At each spatial location, the class with the highest suitability value is assumed to be that which deforestation agents will implement in the absence of the AUD project activity.
 - c) Show the results obtained in maps and summarize the results in Table 17, Table 18 and Table 19 above (Table 17 is optional). Note that by using Method 2, each post-deforestation LU/LC class *fcl* will represent one and only one “zone” *z* (i.e., $fcl = z$).

- d) The model must demonstrably comply with statistical good practice, with evidence of this provided to the VVB at validation.

8.1.4.3 Calculation of Baseline Activity Data Per LU/LC Change Category

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

- 3) Combine the maps showing the polygons of forest classes (icl) that would be deforested during each future year produced in Section 8.1.3.20 with the map showing the post-deforestation LU/LC classes (fcl) prepared in Section 8.1.4.2.
- 4) From the combined datasets produce a new set of maps showing the polygons of LU/LC change categories (ct) for each future year. Some spatial modeling tools are able to produce these maps directly.
- 5) Extract from the maps produced above the number of hectares (i.e., activity data) corresponding to each future year.
- 6) Summarize the results in Table 20 (optional), Table 21 and Table 22 for the baseline validity period and, optionally, for the project crediting period.

Table 20: Baseline Activity Data for LU/LC Change Categories (ct) in the Reference Region

Activity data per LU/LC change category ct in the reference region					Total baseline deforestation in the reference region	
ID_{ct}	1	2	...	I_{ct}	$ABSLRR_t$	$ABSLRR$
Name >					annual	cumulative
Project year t	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
T						

Table 21: Baseline Activity Data For LU/LC Change Categories (*ct*) in the Project Area

Activity data per LU/LC category <i>ct</i> within the project area					Total baseline deforestation in the project area	
<i>ID_{ct}</i>	1	2	...	<i>l_{ct}</i>	<i>ABSLPA_t</i>	<i>ABSLPA</i>
Name >					annual	cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
<i>T</i>						

Table 22: Baseline Activity Data For LU/LC Change Categories (*ct*) in the Leakage Belt

Activity data per LU/LC category <i>ct</i> within the leakage belt					Total baseline deforestation in the leakage belt	
<i>ID_{ct}</i>	1	2	...	<i>l_{ct}</i>	<i>ABSLLK_t</i>	<i>ABSLLK</i>
Name >					annual	cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha/yr	ha
0						
1						
2						
...						
<i>T</i>						

8.1.5 Estimation of Baseline Carbon Stock Changes and Non-CO₂ Emissions (Step 6)

8.1.5.1 Estimation of Baseline Carbon Stock Changes

Before calculating the baseline carbon stock changes, the average carbon stock (t CO₂e/ha) of each LU/LC class must be estimated.

Estimation of the Average Carbon Stocks of Each LU/LC Class

Average carbon stocks must be estimated only for:

- i) Forest classes existing within the project area;³¹
- ii) Forest classes existing within the leakage belt;³²
- iii) Post-deforestation classes projected to exist in the project area in the baseline case;
- iv) Post-deforestation classes projected to exist in the leakage belt in the project case; and
- v) Non-forest classes existing in leakage management zones.

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

- 1) Assess the existing data collected and, where appropriate, use them. It is likely that some existing data may be used to quantify the carbon stocks of one or more classes. These data may be derived from a forest inventory or scientific studies. Analyze these data and use them where the following criteria are fulfilled:
 - a) The data have been measured less than 10 years ago;
 - b) The data are derived from multiple measurement plots;
 - c) All species above a minimum diameter breast height (DBH), which must be no more than 30 cm, are included in the inventories; and
 - d) Data are sampled with good coverage of the classes over which they will be extrapolated.

Existing data that meet the above criteria must only be applied across the classes from which they were representatively sampled. See the latest version of the *GOFC-GOLD sourcebook on REDD* and Gillespie et al. (1992) for methods to analyze these data.

- 2) Collect missing data. For classes for which no existing data are available, data must be obtained from field measurement or use conservative estimates from the literature.

³¹ 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. Where carbon stocks are subject to enhancement, the projection is conservatively omitted.

³² In most cases the forest classes in the leakage belt at the project start date 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. Where carbon stocks are subject to baseline degradation, projecting the changes in carbon stocks is optional and may be conservatively omitted.

- a) **Field measurements:** Where locations of future deforestation are known at the time of field measurements, sample sites should be located where deforestation is expected, in order to achieve maximum accuracy of carbon stock estimates. Design the sampling framework and conduct field measurements following the guidance of Appendix 3 (see also Chapter 4.3 of GPG LULUCF and the sourcebook for LULUCF by Pearson et al., 2005). Summarize the sampling design in the PD and provide a map and coordinates of all sampled locations.
 - b) **Literature estimates:** Carbon stock estimates in similar ecosystems derived from local studies, literature and IPCC default values may be used³³ where the accuracy and conservativeness of the estimates are demonstrated. Where default values are used, the lowest limit of the range or the single value (reduced by 30 percent) given in the literature source for the forest classes and the upper value (or the value increased by 30 percent) given for non-forest classes must be used.
- 3) Calculate the carbon stocks in each forest class present in the project area prior to the year of baseline deforestation. Carbon stocks and boundaries of the forest classes are assumed to remain the same for all years preceding the year when baseline deforestation is projected to occur ($t < t^*$), except in the following cases:
- a) Where in the baseline case the forest within certain polygons of the project area is degrading and losing carbon stocks, a map sequence showing the spatial and temporal sequence of forest classes with successively smaller carbon stocks must be prepared to account for the degradation occurring prior to deforestation. Where the boundary of the degrading forest classes is fixed (i.e., does not change over time), it is sufficient to show the estimated changes in carbon stocks in Table 23 and Table 25 below. 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.
 - b) Where in the baseline case carbon stocks in the forest within certain polygons of the project area are increasing, such changes in carbon stocks are conservatively omitted.
 - c) Where carbon stocks in the project area are decreasing more in the project 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 must be accounted in the project case.
 - d) Where logging activities are present in the baseline, the harvested wood product carbon pool must be estimated and, if significantly higher in the baseline than in the project scenario, it must be accounted.

³³ Attention must be paid to data units. In this methodology, calculations are in t CO₂e while IPCC tables often provide data in t C (1 t C = 44/12 t CO₂e).

- e) Carbon stocks in the harvested wood products carbon pool must be estimated as the sum of planned and unplanned harvesting activities in the baseline case and the additional volume harvested prior to the deforestation event in year t^* (where applicable).

Report the results of estimations in Table 23 (estimated values) and Table 25 (values used in calculations after considering uncertainty discounts according to (6) below).

- 4) Calculate the carbon stocks in each forest class present in the leakage belt prior to the year of baseline deforestation ($t = t^*$). Carbon stocks and boundaries of the forest classes are assumed to remain the same for all years preceding the year in which the baseline deforestation is projected to occur ($t < t^*$), except in the following cases:
 - a) Where in the baseline case the forest within certain polygons of the leakage belt is degrading and losing carbon stocks, changes in carbon stocks may be conservatively omitted and preparing a map sequence is optional for these polygons.

Report the results of the estimations in Table 23 (estimated values) and Table 25 (values used in calculations after considering uncertainty discounts according to (6) below).

Table 23: Carbon Stocks Per Hectare of Initial Forest Classes icl Existing in the Project Area and Leakage Belt – Estimated Values

In this table, forest classes not undergoing degradation in the baseline have a constant carbon stock value each year.

Project year t	Initial forest class icl																	
	Name																	
	ID $_{icl}$																	
	Average carbon stock per hectare $\pm 90\%$ CI																	
	$C_{ab_{icl}}$		$C_{bb_{icl}}$		$C_{dw_{icl}}$		$C_{l_{icl}}$		$C_{SO_{icl}}$		$C_{WP_{icl}}$						$C_{tot_{icl}}$	
										Total carbon stocks in wood products harvested at year t^* (year in which deforestation occurs)								
										Short lived (0–3 years)		Medium lived (3–100 years)		Long lived (>100 years)				
C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	
0																		
1																		
2																		
...																		
T																		

For space reasons, only the sum of $C_{WP_{icl}}$ is shown in the table above. This is the sum of two components, as shown in Table 24 below.

Table 24: Cwp_{icl} Components Summed In Table 23

Project year t	Average carbon stock per hectare $\pm 90\%$ CI																	
	Cwp_{icl}						$Cwp_{icl}^{(2)}$						$Cwp_{icl}^{(3)}$					
	C stock in wood products of planned and unplanned baseline activities (degradation)						C stock in wood products extracted in addition to those extracted in planned/unplanned degradation activities in case of deforestation ($t = t^*$)						Total carbon stocks in wood products supposed to be harvested at year t^* (year in which deforestation occurs)					
	Short lived (0–3 years)		Medium lived (3–100 years)		Long lived (>100 years)		Short lived (0-3 years)		Medium lived (3-100 years)		Long lived (>100 years)		Short lived (0-3 years)		Medium lived (3-100 years)		Long lived (>100 years)	
C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	C stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	
0																		
1																		
2																		
...																		
T																		

Table 25: Carbon Stocks Per Hectare of Initial Forest Classes icl Existing in the Project Area and Leakage Belt – Values After Discounting for Uncertainty

Project year t	Initial forest class icl																		
	Name																		
	ID_{icl}																		
	Average carbon stock per hectare $\pm 90\%$ CI																		
	Cab_{icl}		Cbb_{icl}		Cdw_{icl}		Cl_{icl}		$CSOC_{icl}$		Cwp_{icl} Total carbon stocks in wood products in post-deforestation land uses are considered insignificant						$Ctot_{icl}$		
										Short lived (0-3 years)		Medium lived (3-100 years)		Long lived (>100 years)					
C stock (t CO ₂ e/ ha)		$\pm 90\%$ CI (t CO ₂ e/ ha)		C stock (t CO ₂ e/ ha)		$\pm 90\%$ CI (t CO ₂ e/ ha)		C stock (t CO ₂ e/ ha)		$\pm 90\%$ CI (t CO ₂ e/ ha)		C stock (t CO ₂ e/ ha)		$\pm 90\%$ CI (t CO ₂ e/ ha)		C stock (t CO ₂ e/ ha)		$\pm 90\%$ CI (t CO ₂ e/ ha)	
0																			
1																			
2																			
...																			
T																			
Notes																			

The space “Notes” in Table 25 is intended to insert explanations (or references to explanations) describing how uncertainties have been considered.

Where:

Cab_{icl}	=	Average carbon stock per hectare in above-ground biomass carbon pool of class icl (t CO ₂ e/ha)
Cbb_{icl}	=	Average carbon stock per hectare in below-ground biomass carbon pool of class icl (t CO ₂ e/ha)
Cdw_{icl}	=	Average carbon stock per hectare in dead wood biomass carbon pool of class icl (t CO ₂ e/ha)
Cl_{icl}	=	Average carbon stock per hectare in litter carbon pool of class icl (t CO ₂ e/ha)
$Csoc_{icl}$	=	Average carbon stock per hectare in soil organic carbon pool of class icl (t CO ₂ e/ha)
Cwp_{icl}	=	Average carbon stock per hectare accumulated in the harvested wood products carbon pool between project start and the year of deforestation of class icl (t CO ₂ e/ha)
$Ctot_{icl}$	=	Average carbon stock per hectare in all accounted carbon pools in class icl (t CO ₂ e/ha)

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

- 5) Calculate the long-term (20 year) average carbon stocks of post-deforestation classes. These classes often do not have stable carbon stock because different land uses may be implemented in a time sequence or because the land use after deforestation implies changes in carbon stocks over time (e.g., in tree plantations). The carbon stock of post-deforestation classes must be estimated as the long-term (20 years) average and may be determined from measurements in plots of known age, from long-term studies or from other verifiable sources.
For each post-deforestation LU/LC class, report the calculation of the long-term (20-year) average carbon stock using Table 26.
- 6) Do an uncertainty assessment of all carbon stock estimates. Where the uncertainty of the total average carbon stock ($Ctot_{cl}$) of class cl is less than 10 percent of the average value, the average carbon stock value may be used. Where the uncertainty is higher than 10 percent, the lower boundary of the 90 percent confidence interval must be used in calculations for initial forest classes in the project area and final non-forest classes in the leakage belt, and the higher boundary of the 90 percent confidence interval used for initial forest classes in the leakage belt and final non-forest classes in the project area.
- 7) Calculate the area-weighted average carbon stocks of the post-deforestation LU/LC classes existing within each zone using Table 27.

Table 26: Long-Term (20-Year) Average Carbon Stocks Per Hectare of Post-Deforestation LU/LC Classes Present in the Reference Region

Project year t	Post deforestation class fcl																		
	Name																		
	ID_{fcl}																		
	Average carbon stock per hectare $\pm 90\%$ CI																		
	Cab_{fcl}		Cbb_{fcl}		Cdw_{fcl}		Cl_{fcl}		$CSOC_{fcl}$		Cwp_{fcl} ³⁴						$Ctot_{fcl}$		
Short lived (0-3 years)											Medium lived (3-100 years)		Long lived (>100 years)						
Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	Average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)	average stock (t CO ₂ e/ ha)	$\pm 90\%$ CI (t CO ₂ e/ ha)		
t^*																			
$t^* + 1$																			
$t^* + 2$																			
$t^* + 19$																			
Average																			
Average to be used in calculations (after uncertainty discount)																			

³⁴ This is the total carbon stock in wood products that are expected to be harvested at year t^* (year in which deforestation occurs).

Table 27: Long-Term (20-Year) Area-Weighted Average Carbon Stock Per Zone³⁵

Zone		Post -deforestation LU/LC classes <i>fcl</i>																	Average weighted long-term (20-year) average carbon stocks per zone <i>z</i>	
		Name			Name															
		<i>ID_{fcl}</i>			<i>ID_{fcl} Fcl</i>															
<i>ID_z</i>	Name	C stock (t CO ₂ e/ha)			C stock (t CO ₂ e/ha)					C stock (t CO ₂ e/ha)										
	<i>Ca_{b_{fcl}}</i>	<i>Cb_{b_{fcl}}</i>	<i>Cd_{w_{fcl}}</i>	<i>Cl_{fcl}</i>	<i>Cso_{C_{fcl}}</i>	<i>Cw_{p_{fcl}}</i>	<i>Ca_{b_{fcl}}</i>	<i>Cbb_{fcl}</i>	<i>Cd_{w_{fcl}}</i>	<i>Cl_{fcl}</i>	<i>Cso_{C_{fcl}}</i>	<i>Cw_{p_{fcl}}</i>	<i>Ca_{b_z}</i>	<i>Cb_{b_z}</i>	<i>Cd_{w_z}</i>	<i>Cl_z</i>	<i>Cso_{C_z}</i>	<i>C_{w_{p_z}}</i>	<i>Ct_{ot_z}</i>	
1																				
2																				
...																				
Z																				

³⁵ Insert as many *fcl* classes as needed. Where Method 2 (modeling) is used in Section 8.1.4.2, each zone has only one post-deforestation class *fcl*.

Calculation of Emission Factors

This methodology uses default linear functions to account for the decay in carbon stock in initial forest classes (*icl*) and increase in carbon stock in post-deforestation classes (*fcl*). This is done as follows:

- 1) For above-ground biomass:
 - a) Initial forest classes (*icl*): immediate release of 100 percent of the carbon stock (as estimated in Table 25) is assumed to happen during year $t = t^*$ (year when deforestation occurs).
 - b) Post-deforestation classes (*fcl*) (or their area-weighted average per zone *z*): linear increase from 0 t CO₂e/ha in year $t = t^*$ to 100 percent of the long-term (20-year) average carbon stock (as estimated in Table 27) in year $t = t^* + 9$ is assumed to happen in the 10-year period following deforestation (i.e., 1/10th of the final carbon stock is accumulated each year).
- 2) For below-ground biomass:
 - a) Initial forest classes (*icl*): an annual release of 1/10th of the initial carbon stock (as estimated in Table 25) is assumed to happen each year between $t = t^*$ and $t = t^* + 9$.
 - b) Post-deforestation classes (*fcl*) (or their area-weighted average per zone *z*): linear increase from 0 t CO₂e/ha in year $t = t^*$ to 100 percent of the long-term (20-year) average carbon stock (as estimated in Table 27) in year $t = t^* + 9$ is assumed to happen in the 10-year period following deforestation (i.e., 1/10th of the final carbon stock is accumulated each year).
- 3) For litter:
 - a) Initial forest classes (*icl*): immediate release of 100 percent of the carbon stock (as estimated in Table 25) is assumed to happen at the end of year $t = t^*$.
 - b) Post-deforestation classes (*fcl*) (or their area-weighted average per zone *z*): a linear increase from 0 t CO₂e/ha in year $t = t^*$ to 100 percent of the long-term (20-year) average carbon stock (as estimated in Table 27) in year $t = t^* + 9$ is assumed to happen in the 10-year period following deforestation (i.e., 1/10th of the final carbon stock is accumulated each year).
- 4) For dead wood:
 - a) Initial forest classes (*icl*): an annual release of 1/10th of the initial carbon stock (as estimated in Table 25) is assumed to happen each year between $t = t^*$ and $t = t^* + 9$.
 - b) Post-deforestation classes (*fcl*) (or their area-weighted average per zone *z*): a linear increase from 0 t CO₂e/ha in year $t = t^*$ to 100 percent of the long-term (20-year) average carbon stock (as estimated in Table 27) in year $t = t^* + 9$ is assumed to happen in the 10-year period following deforestation (i.e., 1/10th of the final carbon stock is accumulated each year).
- 5) For wood products:
 - a) Initial forest classes (*icl*), three fractions are considered:

- i) Fraction decaying in less than three years: This short-lived fraction is assumed to be completely released during year t^* (i.e., 100 percent of the stock estimated in Table 25).
 - ii) Fraction decaying between 3 and 100 years: This medium-lived fraction is assumed to decay linearly in 20 years (i.e., 1/20th of the stock estimated in Table 25 each year).
 - iii) Fraction decaying in more than 100 years: This long-lived fraction is assumed to never decay (i.e., it is never released into the atmosphere).
 - b) Post-deforestation classes (fcl) (or their area-weighted average per zone z): it is assumed that carbon stocks in wood products are always insignificant (i.e., carbon stock in all wood products is zero).
- 6) For soil organic carbon:
- a) It is assumed that in a 20-year period, the carbon stock changes from that estimated for initial forest classes (icl) (in Table 25) to that estimated for post-deforestation classes fcl (or their area-weighted average per zone z). The change occurs linearly and may be either a decrease or an increase.
- 7) Where carbon stocks in the soil organic carbon pool are included in the baseline, activity data must be calculated per category (ct) because the linear decay (or increase) function is category-dependent. If Method 2 (modeling) was used in Section 8.1.4.2, Table 20, Table 21 and Table 22 provide the information on activity data per category ct . If Method 1 was used, categories must be defined from initial forest classes icl to zones z . Use Table 28 and Table 29 to describe these categories and combine the Map of Zones of Post-Deforestation Land Uses with the map of initial forest classes and the annual maps of projected deforestation to calculate activity data of these categories (ctz). Report the results in Table 30, Table 31 and Table 32. Do this at least for the baseline validity period and the project area and leakage belt and, optionally, for the entire project crediting period and for the reference region.

Table 28: Potential Land Use and Land Cover Change Matrix

			Initial LU/LC Class <i>icl</i>					
		<i>ID_{icl}</i>	1	2	<i>F_{icl}</i>
	<i>ID_z</i>	Name	B1	B2	...	B4	B5	B50
Zone z	1	Zone 1	i1/z1	i2/z1	i.../z1	i4/z1	i5/z1	iFcl/z1
	2	Zone 2	i1/z2	i2/z2	i.../z2	i4/z2	i5/z2	iFcl/z2
	...	Zone ..	i1/z...	i2/z...	i.../z...	i4/z...	i5/z...	iFcl/z...
	...	Zone ...	i1/z4	i2/z4	i.../z4	i4/z4	i5/z4	iFcl/z4
	...	Zone ...	i1/z5	i2/z5	i.../z5	i4/z5	i5/z5	iFcl/z5
	Z	Zone Z	i1/zZ	i2/zZ	i.../zZ	i4/zZ	i5/zZ	iFcl/zZ

Table 29: List of Land Use and Land Cover Change Categories (*ctz*)

LU/LC Change Category		Initial Forest Class		Post-Deforestation Zone	
<i>ID_{ctz}</i>	Name	<i>ID_{icl}</i>	Name	<i>ID_{icl}</i>	Name
1	ZoneCat1	1	B1	1	Zone 1
2	ZoneCat2	1	B1	2	Zone 2
...	ZoneCat3	1	B1	...	Zone 3
ctz	ZoneCat4	1	B1	4	Zone 4

Table 30: Annual Areas Deforested in Each Category *ctz* Within the Reference Region in the Baseline Case (Baseline Activity Data Per Category *ctz*)³⁶

	Activity Data Per LU/LC Category <i>ctz</i> Within the Reference Region					Total Baseline Deforestation in the Reference Region	
<i>ID_{ct}</i> >	1	2	3	...	<i>ctz</i>	<i>ABSLRR_t</i>	<i>ABSLRR</i>
Name >	ZoneCat1	ZoneCat2	ZoneCat3	ZoneCat4	ZoneCat5	Annual	Cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
<i>T</i>							

Table 31: Annual Areas Deforested in Each Category *ctz* Within the Project Area in the Baseline Case (Baseline Activity Data Per Category (*ctz*))

	Activity Data Per LU/LC Category <i>ctz</i> Within the Project Area					Total Baseline Deforestation in the Project Area	
<i>ID_{ct}</i> >	1	2	3	...	<i>Ctz</i>	<i>ABSLPA_t</i>	<i>ABSLPA</i>
Name >	ZoneCat1	ZoneCat2	ZoneCat3	ZoneCat4	ZoneCat5	Annual	Cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
<i>T</i>							

³⁶ This table is optional.

Table 32: Annual Areas Deforested in Each Category *ctz* Within the Leakage Belt Area in the Baseline Case (Baseline Activity Data Per Category *ctz*)

<i>ID_{ct}</i> >	Activity Data Per LU/LC Category <i>ctz</i> Within the Leakage Belt					Total Baseline Deforestation in the Leakage Belt	
	1	2	3	...	<i>Ctz</i>	<i>ABSLK_t</i>	<i>ABSLK</i>
Name >	ZoneCat1	ZoneCat2	ZoneCat3	ZoneCat4	ZoneCat5	Annual	Cumulative
Project year <i>t</i>	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
<i>T</i>							

Calculation of Baseline Carbon Stock Changes

The choice of method to calculate carbon stock changes depends on whether activity data are available for classes or for categories. Where soil organic carbon is included in the baseline, only Method 2 may be used (i.e., activity data must be defined for categories).

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

$$\begin{aligned}
 \Delta C_{BSLPA_t} = & \sum_{p=1}^P \left(\sum_{icl=1}^{Icl} ABSLPA_{icl,t} \times \Delta C_{p_{icl,t=t^*}} + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-1} \times \Delta C_{p_{icl,t=t^*+1}} \right. \\
 & + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-2} \times \Delta C_{p_{icl,t=t^*+2}} + \dots \\
 & \left. + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-19} \times \Delta C_{p_{icl,t=t^*+19}} \right) \quad (10)
 \end{aligned}$$

Where:

ΔC_{BSLPA_t} = Total baseline carbon stock change within the project area at year *t* (t CO₂e)

$ABSLPA_{icl,t}$	=	Area of initial forest class icl deforested at time t within the project area in the baseline case (ha)
$ABSLPA_{icl,t-1}$	=	Area of initial forest class icl deforested at time $t - 1$ within the project area in the baseline case (ha)
$ABSLPA_{icl,t=t-19}$	=	Area of initial forest class icl deforested at time $t - 19$ within the project area in the baseline case (ha)
$\Delta Cp_{icl,t=t^*}$	=	Average emission factor for carbon pool p in initial forest class icl applicable at time t (t CO ₂ e/ha)
$\Delta Cp_{icl,t=t^*+1}$	=	Average emission factor for carbon pool p in initial forest class icl applicable at time $t = t^* + 1$ (second year after deforestation) (t CO ₂ e/ha)
$\Delta Cp_{icl,t=t^*+19}$	=	Average emission factor for carbon pool p in initial forest class icl applicable at time $t = t^* + 19$ (twentieth year after deforestation) (t CO ₂ e/ha)
icl	=	1, 2, 3, ..., icl initial (pre-deforestation) forest classes (dimensionless)
z	=	1, 2, 3, ..., Z zones (dimensionless)
p	=	1, 2, 3, ..., P carbon pools included in the baseline (dimensionless)
t	=	1, 2, 3, ..., T , a year of the proposed project crediting period (dimensionless)
t^*	=	Year in which area $ABSLPA_{icl,t}$ is deforested in the baseline case

Eq. (10) may be applied to all carbon pools except soil organic carbon. Each carbon pool must be calculated separately to allow significance analysis of each pool in Section 8.4.1.1.

Eq. (10) should also be applied to the leakage belt area and, optionally, to the reference region. Calculations must be made at least for the baseline validity period and, optionally, for the entire project crediting period.

Report the result of the calculations in Table 35 (for the reference region), Table 36 (for the project area) and Table 37 (for the leakage belt area).

Table 33: Emission Factors for Initial Forest Classes icl (Method 1)

Year after deforestation		$\Delta Cab_{icl,t}$	$\Delta Cbb_{icl,t}$	$\Delta Cdw_{icl,t}$	$\Delta Cl_{icl,t}$	$\Delta CSOC_{icl,t}$ ³⁷	$\Delta Cwp_{icl,t}$		
							Short-lived	Medium-lived	Long-lived
1	t^*	$-Cab_{icl,t}$	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	$-Cl_{icl,t}$	N/A	$-Cwp_{icl,t=t^*}$	$-1/20 \times Cwp_{icl,t=t^*}$	0
2	$t^* + 1$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
3	$t^* + 2$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
4	$t^* + 3$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
5	$t^* + 4$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
6	$t^* + 5$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
7	$t^* + 6$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
8	$t^* + 7$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
9	$t^* + 8$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
10	$t^* + 9$	0	$-1/10 \times Cbb_{icl,t=t^*}$	$-1/10 \times Cdw_{icl,t=t^*}$	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
11	$t^* + 10$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
12	$t^* + 11$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
13	$t^* + 12$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
14	$t^* + 13$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
15	$t^* + 14$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
16	$t^* + 15$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
17	$t^* + 16$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
18	$t^* + 17$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
19	$t^* + 18$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
20	$t^* + 19$	0	0	0	0	N/A	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
21-T	$t^* + 20, \dots$	0	0	0	0	N/A	0	0	0

³⁷ Use Method 2 to calculate $\Delta CSOC_{icl,t}$

Table 34: Emission Factors for Land Use Change Categories (ct or ctz) (Method 2)

Year after deforestation	$\Delta Cab_{ctz,t}$	$\Delta Cbb_{ctz,t}$	$\Delta Cdw_{ctz,t}$	$\Delta Cl_{ctz,t}$	$\Delta CSoc_{ctz,t}$	$\Delta Cwp_{ctz,t}$			
						Short-lived	Medium-lived	Long-lived	
1	t^*	$-Cab_{icl,t} + 1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$-Cl_{icl,t} + 1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	$-Cwp_{icl,t=t^*}$	$-1/20 \times Cwp_{icl,t=t^*}$	0
2	$t^* + 1$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
3	$t^* + 2$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
4	$t^* + 3$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
5	$t^* + 4$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
6	$t^* + 5$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
7	$t^* + 6$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
8	$t^* + 7$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
9	$t^* + 8$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
10	$t^* + 9$	$1/10 \times Cab_z$	$-1/10 \times Cbb_{icl,t=t^*} + 1/10 \times Cbb_z$	$-1/10 \times Cdw_{icl,t=t^*} + 1/10 \times Cdw_z$	$1/10 \times Cl_z$	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
11	$t^* + 10$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
12	$t^* + 11$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
13	$t^* + 12$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
14	$t^* + 13$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
15	$t^* + 14$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
16	$t^* + 15$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
17	$t^* + 16$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0
18	$t^* + 17$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t=t^*}$	0

Year after deforestation		$\Delta Cab_{ctz,t}$	$\Delta Cbb_{ctz,t}$	$\Delta Cdw_{ctz,t}$	$\Delta Cl_{ctz,t}$	$\Delta CSOC_{ctz,t}$	$\Delta Cwp_{ctz,t}$		
							Short-lived	Medium-lived	Long-lived
19	$t^* + 18$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t^*}$	0
20	$t^* + 19$	0	0	0	0	$1/20 \times (CSOC_{icl,t^*} - CSOC_z)$	0	$-1/20 \times Cwp_{icl,t^*}$	0
21-T	$t^* + 20, \dots$	0	0	0	0	0	0	0	0

Table 35: Baseline Carbon Stock Change for Selected Carbon Pools in the Reference Region (Method 1)

Carbon Stock Changes in the Aboveground Biomass per Initial Forest Class icl					Total Carbon Stock Change in Aboveground Biomass of Initial Forest Classes in the Reference Region		Carbon Stock Changes in Aboveground Biomass Per Post-deforestation Zone z					Total Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Reference Region		Total Net Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Reference Region	
ID $_{icl}$ >	1	2	...	id	$\Delta Cab_{BSLRR_{icl,t}}$ Annual	$\Delta Cab_{BSLRR_{icl}}$ Cumulative	ID $_{iz}$ >	1	2	...	z	$\Delta Cab_{BSLRR_{z,t}}$ Annual	ΔCab_{BSLRR_z} Cumulative	ΔCab_{BSLRR_t} Annual	ΔCab_{BSLRR} Cumulative
Name>							Name>								
Project year t	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	Project year t	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0							0								
1							1								
2							2								
...							...								
T							T								

Table 35 illustrates how to determine baseline carbon stock for aboveground biomass. Prepare a similar table for below-ground biomass, dead wood, litter and wood products when relevant. Use Method 2 if soil organic carbon is included.

Table 36: Baseline Carbon Stock Change for Selected Carbon Pools in the Project Area (Method 1)

Carbon Stock Changes in Aboveground Biomass per Initial Forest Class icl					Total Carbon Stock Change in Aboveground Biomass of Initial Forest Classes in the Project Area		Carbon Stock Changes in Aboveground Biomass Per Post-deforestation Zone z					Total Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Project Area		Total Net Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Project Area	
ID $_{icl}$ >	1	2	...	id	ΔCab $BSLPA_{icl,t}$ Annual	ΔCab $BSLPA_{icl}$ Cumulative	ID $_{iz}$ >	1	2	...	z	ΔCab $BSLPA_{z,t}$ Annual	ΔCab $BSLPA_z$ Cumulative	ΔCab $BSLPA_t$ Annual	ΔCab $BSLPA$ Cumulative
Name>							Name>								
Project year t	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	Project year t	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e
0							0								
1							1								
2							2								
...							...								
T							T								

Table 36 illustrates how to determine baseline carbon stock for aboveground biomass. Prepare a similar table for belowground biomass, dead wood, litter and wood products. Use Method 2 if soil organic carbon is included.

Table 37: Baseline Carbon Stock Change for Selected Carbon Pools in the Leakage Belt (Method 1)

Carbon Stock Changes in Aboveground Biomass Per Initial Forest Class <i>icl</i>					Total Carbon Stock Change in Aboveground Biomass of Initial Forest Classes in the Leakage Belt		Carbon Stock Changes in Aboveground Biomass Per Post-deforestation Zone <i>z</i>					Total Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Leakage Belt		Total Net Carbon Stock Change in Aboveground Biomass of Post-deforestation Zones in the Leakage Belt	
<i>ID_{icl}</i> >	1	2	...	id	$\Delta Cab_{BSLLK_{icl,t}}$ Annual	$\Delta Cab_{BSLLK_{icl}}$ Cumulative	<i>ID_{iz}</i> >	1	2	...	z	$\Delta Cab_{BSLLK_{z,t}}$ Annual	ΔCab_{BSLLK_z} Cumulative	ΔCab_{BSLLK_t} Annual	ΔCab_{BSLLK} Cumulative
Name>							Name>								
Project year <i>t</i>	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	Project year <i>t</i>	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0							0								
1							1								
2							2								
...							...								
T							T								

Table 37 illustrates how to determine baseline carbon stock for aboveground biomass. Prepare a similar table for belowground biomass, dead wood, litter and wood products. Use Method 2 if soil organic carbon is included.

Where activity data are available for categories (Method 2), first calculate emission factors for each category (Table 34) then calculate baseline carbon stock changes for the reference region (optional), project area and leakage belt by multiplying activity data by their corresponding emission factors. Do this at least for the baseline validity period and, optionally, for the entire project crediting period.

Report the result of the calculations in Table 38 (for the reference region), Table 39 (for the project area) and Table 40 (for the leakage belt).

Note – it is possible (and simpler) to calculate baseline carbon stock changes using Method 1 for all carbon pools (except soil organic carbon) and, where soil organic carbon is included, using Method 2 just for this pool.

Table 38: Baseline Carbon Stock Change for Selected Carbon Pools in the Reference Region (Method 2)

Project year t	Activity Data Per Category \times Emission Factor for Aboveground Biomass in the Reference Region								Total Baseline Carbon Stock Change in the Reference Region	
	ID_{ct}	= 1	ID_{ct}	= 2	ID_{ct}	= . . .	ID_{ct}	= C_t	Annual	Cumulative
	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLRR_t$	$\Delta CabBSLRR$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 38 illustrates how to determine baseline carbon stock for above-ground biomass. Prepare a similar table for belowground biomass, dead wood, litter, wood products and soil organic carbon.

Table 39: Baseline Carbon Stock Change for Selected Carbon Pools in the Project Area (Method 2)

Project year t	Activity Data Per Category \times Emission Factor for Aboveground Biomass in the Project Area								Total Baseline Carbon Stock Change in the Project Area	
	ID_{ct}	= 1	ID_{ct}	= 2	ID_{ct}	= ...	ID_{ct}	= C_t	Annual	Cumulative
	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLPA_t$	$\Delta CabBSLPA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 39 illustrates how to determine baseline carbon stock for aboveground biomass. Prepare a similar table for belowground biomass, dead wood, litter, wood products and soil organic carbon.

Table 40: Baseline Carbon Stock Change in the Leakage Belt (Method 2)

Project year t	Activity Data Per Category × Emission Factor for Aboveground Biomass in the Leakage Belt								Total Baseline Carbon Stock Change in the Leakage Belt	
	ID_{ct}	= 1	ID_{ct}	= 2	ID_{ct}	= . . .	ID_{ct}	= C_t	Annual	Cumulative
	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLLK_t$	$\Delta CabBSLLK$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 40 illustrates how to determine baseline carbon stock for aboveground biomass. Prepare a similar table for belowground biomass, dead wood, litter, wood products and soil organic carbon.

8.1.5.2 Baseline Non-CO₂ Emissions from Forest Fires

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

Conversion of forest to non-forest involving fires is a source of emissions of non-CO₂ gases (CH₄ and N₂O). Where 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, CH₄ emissions from biomass burning may 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 CO₂ emissions from forest fires should be ignored to avoid double counting.

To estimate non-CO₂ 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 burned in each carbon pool ($P_{burnt,p}$) 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 may be estimated as follows.

$$EBB_{tot_{icl,t}} = EBB_{N2O_{icl,t}} + EBB_{CH4_{icl,t}} \quad (11)$$

Where:

$EBB_{tot_{icl,t}}$ = Total GHG emissions from biomass burning in forest class icl in year t (t CO₂e/ha)

$EBB_{N2O_{icl,t}}$ = N₂O emissions from biomass burning in forest class icl in year t (t CO₂e/ha)

$EBB_{CH4_{icl,t}}$ = CH₄ emissions from biomass burning in forest class icl in year t (t CO₂e/ha)

$$EBB_{N2O_{icl,t}} = EBB_{CO2_{icl,t}} \times \frac{12}{44} \times NCR \times ER_{N2O} \times \frac{44}{28} \times GWP_{N2O} \quad (12)$$

$$EBB_{CH4_{icl,t}} = EBB_{CO2_{icl,t}} \times \frac{12}{44} \times ER_{CH4} \times \frac{16}{12} \times GWP_{CH4} \quad (13)$$

Where:³⁸

$EBB_{CO2_{icl,t}}$ = Per hectare CO₂ emissions from biomass burning in slash and burn in forest class icl in year t (t CO₂e/ha)

$EBB_{N2O_{icl,t}}$ = Per hectare N₂O emissions from biomass burning in slash and burn in forest class icl at year t (t CO₂e/ha)

$EBB_{CH4_{icl,t}}$ = Per hectare CH₄ emissions from biomass burning in slash and burn in

³⁸ Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in IPCC GPG-LULUCF.

		forest class <i>icl</i> at year <i>t</i> (t CO ₂ e/ha)
<i>NCR</i>	=	Nitrogen to carbon ratio (IPCC default value = 0.01) (dimensionless)
<i>ER_{N2O}</i>	=	Emission ratio for N ₂ O (IPCC default value = 0.007)
<i>ER_{CH4}</i>	=	Emission ratio for CH ₄ (IPCC default value = 0.012)
<i>GWP_{N2O}</i>	=	Global Warming Potential for N ₂ O (IPCC default value = 310 for the first commitment period)
<i>GWP_{CH4}</i>	=	Global Warming Potential for CH ₄ (IPCC default value = 21 for the first commitment period)

$$EBBCO2_{icl,t} = Fburnt_{icl} \times \sum_{p=1}^P (C_{p,icl,t} \times Pburnt_{p,icl} \times CE_{p,icl}) \quad (14)$$

Where:

<i>EBBCO2_{icl,t}</i>	=	Per hectare CO ₂ emissions from biomass burning in forest class <i>icl</i> in year <i>t</i> (t CO ₂ e/ha)
<i>Fburnt_{icl}</i>	=	Proportion of forest area burned during the historical reference period in forest class <i>icl</i> (%)
<i>C_{p,icl,t}</i>	=	Average carbon stock per hectare in carbon pool <i>p</i> burned in forest class <i>icl</i> in year <i>t</i> (t CO ₂ e/ha)
<i>Pburnt_{p,icl}</i>	=	Average proportion of mass burned in carbon pool <i>p</i> in forest class <i>icl</i> (%)
<i>CE_{p,icl}</i>	=	Average combustion efficiency of carbon pool <i>p</i> in forest class <i>icl</i> (dimensionless)
<i>p</i>	=	Combustible carbon pool (above-ground biomass, dead wood, litter)
<i>icl</i>	=	1, 2, 3, ..., <i>icl</i> (pre-deforestation) forest classes
<i>t</i>	=	1, 2, 3, ..., <i>T</i> , a year of the proposed project crediting period (dimensionless)

The combustion efficiencies may be chosen from Table 3.A.14 of IPCC GPG LULUCF. Where no appropriate combustion efficiency is available, 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, where data are available. Emission factors for use with the 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 Table 41.

Table 41: Parameters Used to Calculate Non-CO₂ Emissions from Forest Fires

Initial Forest Class		Parameters																			
		$F_{burnt,icl}$	C_{ab}	C_{dw}	CI	$P_{burnt_{ab},icl}$	$P_{burnt_{dw},icl}$	$P_{burnt_t,icl}$	$CE_{ab,icl}$	$CE_{dw,icl}$	$CE_{t,icl}$	$ECO2-ab$	$ECO2-dw$	$ECO2-I$	$EBBCO2_{tot}$	$EBBN2O_{icl}$	$EBBCH4_{icl}$	$EBB_{tot,icl}$			
ID	Cl	Na	me	%	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	%	%	%	%	%	%	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	t CO ₂ e/ha	
1																					
2																					
..																					
icl																					

Finally, using the parameters specified in Table 41 and the projected activity data for forest classes calculate the projected total non-CO₂ emissions from forest fires and report the results in Table 42.

Table 42: Baseline Non-CO₂ Emissions from Forest Fires in the Project Area

Project year t	Emissions of Non-CO ₂ Gases 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}	= ...	ID_{icl}	= icl		
	$ABS_{LPA_{icl,t}}$	$EBBBS_{L_{tot,icl}}$	$ABS_{LPA_{icl,t}}$	$EBBBS_{L_{tot,icl}}$	$ABS_{LPA_{icl,t}}$	$EBBBS_{L_{tot,icl}}$	$ABS_{LPA_{icl,t}}$	$EBBBS_{L_{tot,icl}}$	Annual	Cumulative
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	$EBBBS_{LPA_t}$	$EBBBS_{LPA}$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

8.2 Project Emissions

8.2.1 Ex Ante Estimation of Actual Carbon Stock Changes and Non-CO₂ Emissions in the Project Area (Step 7)

The goal of this step is to provide an ex ante estimate of future carbon stock changes and non-CO₂ emissions from forest fires under the project scenario (“actual”). Actual carbon stock changes and GHG emissions are subject to MRV-A, but they are estimated at the beginning of a baseline validity period to assist in guiding optimal implementation of emission reduction measures, and to allow reasonable projections of revenue to be made.

8.2.1.1 Ex Ante Estimation of Actual Carbon Stock Changes

Actual carbon stock changes occur due to the following:

- 1) Planned activities within the project area;
- 2) Unplanned deforestation that is unavoidable; and
- 3) Possible future catastrophic events – which are unpredictable and are therefore excluded from the ex ante assessment.

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 change the carbon stocks of these areas compared to the baseline. Such activities are:

- i) Planned deforestation (e.g., to build project infrastructure);
- ii) Planned degradation (e.g., timber logging, fuel-wood collection, charcoal production); and
- iii) Protection without harvesting leading to carbon sequestration in forest classes that at project start are below their carbon stock potential at maturity in situ.

Where the project activity generates a significant decrease in carbon stocks during the baseline validity period, the carbon stock change must be estimated ex ante and measured ex post.

Where the decrease is not significant, it must not be accounted and ex post monitoring is not required.

Where the project activity generates an increase in carbon stocks, the carbon stock change is conservatively ignored.

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

Where the AUD project activity includes more planned deforestation, harvesting of timber,³⁹ fuel-wood collection or charcoal production than the baseline case, do the following:

³⁹ Ignoring carbon stocks in long-lived wood products is conservative under the project scenario.

- 1) 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.
- 2) Prepare maps showing the annual locations of the planned activities.
- 3) Identify the forest classes that are located within these polygons.
- 4) Define activity data (annual areas) for each forest class, according to the planned interventions and types of intervention.
- 5) Estimate the impact of the planned activities on carbon stocks as follows:
 - a) Planned deforestation: Conservatively assume that 100 percent of carbon stocks are lost at the year of planned deforestation.
 - b) Areas subject to more planned logging, fuel-wood collection or charcoal production than 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.
 - c) Summarize the result of the previous assessments and calculations in Table 43–Table 46. Table 44 and Table 45 are only filled out ex post (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 uncontrolled forest fires and other catastrophic events that may occur within the project area during project implementation.

Table 43: Ex Ante Estimated Actual Carbon Stock Decrease Due to Planned Deforestation in the Project Area

Project year t	Areas of Planned Deforestation × Carbon Stock Change (Decrease) in the Project Area								Total Carbon Stock Decrease due to Planned Deforestation	
	ID_{cl}	= 1	ID_{cl}	= 2	ID_{cl}	= . . .	ID_{cl}	= I_{cl}	Annual	Cumulative
	$APDPA_{I_{cl},t}$	$C_{tot_{I_{cl},t}}$	$APDPA_{I_{cl},t}$	$C_{tot_{I_{cl},t}}$	$APDPA_{I_{cl},t}$	$C_{tot_{I_{cl},t}}$	$APDPA_{I_{cl},t}$	$C_{tot_{I_{cl},t}}$	$\Delta CPDdPA_t$	$\Delta CPDdPA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 44: Ex Ante Estimated Actual Carbon Stock Decrease Due to Planned Logging Activities in the Project Area

Project year t	Areas of Planned Logging Activities × 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}	= ...	ID_{cl}	= I_{cl}	Annual	Cumulative
	$APLPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APLPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APLPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APLPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$\Delta CPLdPA_t$	$\Delta CPLdPA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 45: 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 and Charcoal Activities × Carbon Stock Change (Decrease) in the Project Area								Total Carbon Stock Decrease due to Planned Fuel-wood and Charcoal Activities	
	ID_{cl}	= 1	ID_{cl}	= 2	ID_{cl}	= ...	ID_{cl}	= I_{cl}	Annual	Cumulative
	$APFPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APFPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APFPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$APFPA_{I_{cl},t}$	$\Delta Ct_{otI_{cl},t}$	$\Delta CPFdPA_t$	$\Delta CPFdPA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 46: 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
	$\Delta CPDdPA_t$	$\Delta CPDdPA$	$\Delta CPLdPA_t$	$\Delta CPLdPA$	$\Delta CPFdPA_t$	$\Delta CPFdPA$	$\Delta CPAdPA_t$	$\Delta CPAdPA$
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0								
1								
2								
...								
T								

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 is actually reduced in the project case depends on the effectiveness of the proposed activities, which it is not possible to measure ex ante. Ex post measurements of project results are important to determine actual emission reductions.

To allow ex ante projections to be made, the project proponent must make a conservative and realistic 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 is the ex ante estimated emissions from unplanned deforestation in the project case. EI must be justified based on the activities to be implemented by the project.

$$\Delta CUDdPA_t = \Delta CBSL_t \times (1 - EI) \quad (16)$$

Where:

$\Delta CUDdPA_t$ = Total ex ante actual carbon stock change due to unavaoided unplanned deforestation at year t in the project area (t CO_{2e})

$\Delta CBSL_t$ = Total baseline carbon stock change at year t in the project area (t CO_{2e})

EI = Ex ante estimated Effectiveness Index (%)
 t = 1, 2, 3, ..., T , a year of the proposed project crediting period (dimensionless)

Ex Ante Estimated Net Actual Carbon Stock Changes in the Project Area

Summarize the result of the previous assessments in Table 47.

Table 47: 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 Decrease due to Unavoided Unplanned Deforestation		Total Carbon Stock Change in the Project Case	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CUDdPA_t$	$\Delta CUDdPA$	$\Delta CPSPA_t$	$\Delta CPSPA$
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0						
1						
2						
...						
T						

8.2.1.2 Ex Ante Estimation of Actual Non-CO₂ Emissions from Forest Fires

Where forest fires have been included in the baseline scenario, non-CO₂ 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 48.

$$EBBPSPA_t = EBBBSPA_t \times (1 - EI) \quad (17)$$

Where:

$EBBPSPA_t$ = Total ex ante actual non-CO₂ emissions from forest fires due to unavoidable unplanned deforestation at year t in the project area (t CO_{2e})
 $EBBBSPA_t$ = Total non-CO₂ emissions from forest fires at year t in the project area (t CO_{2e})
 EI = Ex ante estimated Effectiveness Index (%)
 t = 1, 2, 3, ..., T , a year of the proposed project crediting period (dimensionless)

Table 48: Total Ex Ante Estimated Actual Emissions of Non-CO₂ Gases Due to Forest Fires in the Project Area

Project year <i>t</i>	Total Ex Ante Estimated Actual Non-CO ₂ Emissions from Forest Fires in the Project Area	
	<i>EBBPSPA_t</i>	<i>EBBPSPA</i>
	Annual	Cumulative
	t CO ₂ e	t CO ₂ e
0		
1		
2		
...		
<i>T</i>		

8.2.1.3 Total Ex Ante Estimations for the Project Area

Table 49: Total Ex Ante Estimated Actual Net Carbon Stock Changes and Emissions of Non-CO₂ Gases in the Project Area

Project year <i>t</i>	Total Ex Ante Carbon Stock Decrease 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
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CUDdPA_t$	$\Delta CUDdPA$	$\Delta CPSPA_t$	$\Delta CPSPA$	<i>EBBPSPA_t</i>	<i>EBBPSPA</i>
	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e
0								
1								
2								
...								
<i>T</i>								

8.2.2 Ex Post Monitoring of Carbon Stock Changes and GHG Emissions Within the Project Area

This task involves:

- 1) Monitoring of project implementation;
- 2) Monitoring of land use and land cover change;
- 3) Monitoring of carbon stocks and non-CO₂ emissions; and
- 4) Monitoring of impacts of natural disturbances and other catastrophic events.

8.2.2.1 Monitoring Project Implementation

Project activities implemented within the project area should be consistent with the project area management plans and the PD. All maps and records generated during project implementation should be conserved and made available to the VVB at verification to demonstrate that the AUD project activity has actually been implemented.

8.2.2.2 Monitoring Land Use and Land Cover Change Within the Project Area

Change categories subject to MRV are listed in Table 50.

Table 50: Categories Subject to MRV

ID	Type	Conditions under which monitoring is mandatory	Explanation
I	Area of forest land converted to non-forest land	Mandatory in all AUD project activities	
II	Area of forest land undergoing carbon stock reductions	Mandatory only for AUD project activities with 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 increases	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 may only be accounted on areas that are expected to be deforested in the baseline case.

Monitoring must be carried out by creating ex post tables of activity data per stratum (Table 9, Table 10 and Table 11); per initial forest class *icI* (Table 13, Table 14 and Table 15); per post-deforestation zone *z* (Table 17, Table 18 and Table 19) and, where applicable, per category of land use change *ct* (Table 20, Table 21 and Table 22) or *ctz* (Table 30, Table 31 and Table 32).

8.2.2.3 Monitoring of Carbon Stock Changes

In most cases, the ex ante estimated average carbon stocks per LU/LC class (or emission factors per LU/LC change category) will not change during a baseline validity period and monitoring carbon stocks will not be necessary.

However, monitoring carbon stocks is mandatory in the following cases:

- 1) Within the project area:
 - a) Areas subject to significant carbon stock decrease in the project scenario according to the ex ante assessment. These are 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 8.2.2.5 below for more detailed guidance.
- 2) Within leakage management zones: 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.

Where carbon stocks are monitored, the methods for sampling and measuring carbon stocks described in Appendix 3 must be used.

Project proponents may wish to take additional carbon stock measurements during project implementation to improve accuracy and generate additional credits. Where new and more accurate carbon stock data become available, these may be used to estimate the net GHG emission reductions in the subsequent baseline validity period. For the current baseline validity period, new data on carbon stocks may only be used where the data are validated by a VVB. If new data are used in the current baseline validity 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 23	Ex post carbon stock per hectare of initial forest classes <i>icl</i> existing in the project area and leakage belt
Table 26	Ex post carbon stock per hectare of initial final classes <i>fcl</i> existing in the project area and leakage belt
Table 43	Ex post carbon stock decrease due to planned and unplanned deforestation in the project area

Table 44	Ex post carbon stock decrease due to planned logging activities
Table 45	Ex post carbon stock decrease due to planned fuel-wood and charcoal activities
Table 46	Total ex post carbon stock decrease due to planned activities in the project area
Table 51	Ex post carbon stock decrease due to forest fires (see below)
Table 52	Ex post carbon stock decrease due to catastrophic events (see below and Section 8.2.2.5)
Table 53	Total ex post carbon stock decrease due to forest fires and catastrophic events (see below).

Table 51: Ex Post Actual Carbon Stock Decrease Due to Forest Fires in the Project Area

Project year t	Areas Affected by Forest Fires × Carbon Stock Change (Decrease)								Total Carbon Stock Decrease due to Forest Fires	
	ID_{cl}	= 1	ID_{cl}	= 2	ID_{cl}	= . . .	ID_{cl}	= lcl	Annual	Cumulative
	$AUFPA_{lcl,t}$	$\Delta Ct_{ot_{lcl,t}}$	$AUFPA_{lcl,t}$	$\Delta Ct_{ot_{lcl,t}}$	$AUFPA_{lcl,t}$	$\Delta Ct_{ot_{lcl,t}}$	$AUFPA_{lcl,t}$	$\Delta Ct_{ot_{lcl,t}}$	$\Delta CUFdPA_t$	$\Delta CUFdFA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 52: Ex Post Carbon Stock Decrease Due to Catastrophic Events in the Project Area

Project year t	Areas Affected by Catastrophic Events × Carbon Stock Change (Decrease)								Total Carbon Stock Decrease due to Catastrophic Events	
	ID_{cl}	= 1	ID_{cl}	= 2	ID_{cl}	= ...	ID_{cl}	= lcl	Annual	Cumulative
	$ACPA_{lcl,t}$	$\Delta Ctot_{lcl,t}$	$ACPA_{lcl,t}$	$\Delta Ctot_{lcl,t}$	$ACPA_{lcl,t}$	$\Delta Ctot_{lcl,t}$	$ACPA_{lcl,t}$	$\Delta Ctot_{lcl,t}$	$\Delta CUCdPA_t$	$\Delta CUCdPA$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 53: 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
	$\Delta CUFdPA_t$	$\Delta CUFdPA$	$\Delta CUCdPA_t$	$\Delta CUCdPA$	$\Delta CFCdPA_t$	$\Delta CFCdPA$
	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e
0						
1						
2						
...						
T						

Table 54: Ex Post Estimated Net Carbon Stock Change in the Project Area

Project year t	Total Carbon Stock Decrease due to Planned Activities		Total Carbon Stock Decrease due to Fires and Catastrophic Events		Total Ex Post Carbon Stock Change in the Project Case	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	ΔCPA_{dPA_t}	ΔCPA_{dPA}	ΔCFC_{dPA_t}	ΔCFC_{dPA}	$\Delta CPSPA_t$	$\Delta CPSPA$
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0						
1						
2						
...						
T						

8.2.2.4 Monitoring Non-CO₂ Emissions from Forest Fires

Non-CO₂ emissions from forest fires are subject to monitoring and accounting, where significant. In this case, under the project scenario monitor the variables in Table 41 within the project area and report the results in Table 42.

8.2.2.5 Monitoring Impacts of Natural Disturbances and Other Catastrophic Events

Decreases in carbon stocks and increases in GHG emissions (e.g., from forest fires) due to natural disturbances (such as hurricanes, earthquakes, volcanic eruptions, tsunamis, flooding, drought,⁴⁰ fires, tornados or winter storms) or anthropogenic 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, where significant. Use Table 51, Table 52 and Table 53 to report carbon stock decreases that may happen on disturbed lands after the occurrence of an event. Use Table 41 and Table 42 to report emissions from forest fires.

⁴⁰ 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; Page et al., 2002; Siegert et al., 2001). If droughts become more severe in the future through more frequent and severe El Niño episodes (Timmermann et al., 1999; Trenberth and Hoar, 1997), or the dry season becomes longer due to deforestation-induced rainfall inhibition (Nobre et al., 1991; Silva-Dias et al., 2002) or there are rainfall reductions due to climate change (Cox et al., 2000; White et al., 1999), then substantial portions of the 200 Gt of carbon stored globally in tropical forest trees may be transferred to the atmosphere in the coming decades (Santilli et al., 2005).

8.2.2.6 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 49 Total ex post estimated actual net changes in carbon stocks and emissions of GHG gases in the project area

8.3 Leakage Emissions

8.3.1 Ex Ante Estimation of Leakage (Step 8)

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. Leakage is estimated ex ante to assist in guiding the design of optimal leakage prevention measures, identify sources of leakage that may be significant, and therefore subject to MRV, and to allow reasonable projections of carbon and other project revenues to be made.

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

- 1) Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention measures (Section 8.3.1.1); and
- 2) Decrease in carbon stocks and increase in GHG emissions associated with activity displacement leakage (Section 8.3.1.2).

8.3.1.1 Ex Ante Estimation of 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 zones (outside the project area) that together will replace baseline income, product generation and livelihood of the agents as much as possible, so that deforestation is reduced and the risk of displacement minimized.

Where 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. Where such decrease in carbon stock or increase in GHG emission is significant, it must be accounted and monitoring is required. Where it is not significant, it must not be accounted and ex post monitoring is not necessary.

Where leakage prevention activities are associated with other VCS or UNFCCC registered (and VCS-approved) 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 zones may cause a decrease in carbon stocks or an increase in GHG emissions:

- a) Carbon stock changes due to activities implemented in leakage management zones
- b) Methane (CH₄) and nitrous oxide (N₂O) emissions from livestock intensification (involving a change in animal diet and/or animal numbers)

Note that N₂O 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.

Carbon Stock Changes due to Activities Implemented in Leakage Management Zones

Leakage prevention activities that generate a decrease in carbon stocks should be avoided. Where such activities are necessary, the decrease in carbon stock associated with the leakage prevention activity must be estimated ex ante and accounted, where significant.

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

- 1) Prepare a list of the planned leakage prevention activities and briefly describe each of them in the PD.
- 2) Prepare a map of the planned leakage prevention activities showing annual areas of intervention and type of intervention.
- 3) Identify the areas where leakage prevention activities will impact carbon stocks.
- 4) Identify the non-forest classes⁴¹ existing within these areas in the baseline case.
- 5) Measure the carbon stocks in the identified classes or use conservative literature estimates for each of the identified classes. Where classes have changing carbon stocks in the baseline, project carbon stocks using growth data and other relevant and verifiable sources of information.
- 6) Report in Table 55 the projected baseline carbon stock changes in the leakage management zones.
- 7) According to the planned interventions, estimate projected carbon stocks in the leakage management zones under the project scenario. Use conservative growth projections. Report the result in Table 56.
- 8) Calculate the net carbon stock changes that the planned leakage prevention measures are expected to cause during the baseline validity period and, optionally, the project crediting period. Report the results of the calculations in Table 57.
 - a) Where the net sum of carbon stock changes within a monitoring period is more than zero, leakage prevention measures are not causing any carbon stock

⁴¹ Forest classes must not be present in leakage management zones at the project start date (see Section 5.1.4).

decrease. The net increase must conservatively be ignored in the calculation of net GHG emission reductions of the project activity.

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

Table 55: Ex Ante Estimated Carbon Stock Change in Leakage Management Zones in the Baseline Case

Project year t	Carbon Stock Changes in Leakage Management Zones in the Baseline Case								Total Carbon Stock Change in the Baseline Case	
	ID_{icl}	= 1	ID_{icl}	= 2	ID_{icl}	= ...	ID_{icl}	= lcl	Annual	Cumulative
	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$Ctot_{icl,t}$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 56: Ex Ante Estimated Carbon Stock Change in Leakage Management Zones in the Project Case

Project year t	Carbon Stock Changes in Leakage Management Zones in the Project Case								Total Carbon Stock Change in the Project Case	
	ID_{fcl}	= 1	ID_{fcl}	= 2	ID_{fcl}	= ...	ID_{fcl}	= Fcl	Annual	Cumulative
	$APSLK_{fcl,t}$	$Ctot_{fcl,t}$	$APSLK_{fcl,t}$	$Ctot_{fcl,t}$	$APSLK_{fcl,t}$	$Ctot_{fcl,t}$	$APSLK_{fcl,t}$	$Ctot_{fcl,t}$	$\Delta CPSLK_t$	$\Delta CPSLK$
	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	ha	t CO ₂ e/ha	t CO ₂ e	t CO ₂ e
0										
1										
2										
...										
T										

Table 57: Ex Ante Estimated Net Carbon Stock Change in Leakage Management Zones

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
	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CPSLK_t$	$\Delta CPSLK$	$\Delta CLPMLK_t$	$\Delta CLPMLK$
	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e
0						
1						
2						
...						
T						

Ex Ante Estimation of CH₄ and N₂O Emissions from Grazing Animals

To estimate the increase in emissions of CH₄ and N₂O from grazing animals in leakage management zones, do the following:

- 1) Specify the annual areas that will have grazing activities in the leakage management zones.
- 2) Briefly describe the types of animal, forage and manure management. Use Table 58 to report the key parameters required to calculate GHG emissions.
- 3) 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 increases in GHG emissions.
- 4) Methods to estimate emissions from enteric fermentation and manure management are given in Appendix 4. Perform the final calculations using Eq. (18) and report the results in Table 59.

The GHG emissions are estimated as follows:

$$EgLK_t = ECH4ferm_t + ECH4man_t + EN2Oman_t \quad (18)$$

Where:

$EgLK_t$	=	Emissions from grazing animals in leakage management zones in year t (t CO ₂ e/yr)
$ECH4ferm_t$	=	CH ₄ emissions from enteric fermentation in leakage management zones at year t (t CO ₂ e/yr)
$ECH4man_t$	=	CH ₄ emissions from manure management in leakage management zones in year t (t CO ₂ e/yr)
$EN2Oman_t$	=	N ₂ O emissions from manure management in leakage management zones at year t (t CO ₂ e/yr)
t	=	1, 2, 3, ..., T years of the project crediting period (dimensionless)

Table 58: Parameters Used for the Ex Ante Estimation of GHG Emissions from Grazing Activities

Parameter	Value used in calculations	Unit	Description
<i>EF1</i>		kg CH ₄ /head/y	Enteric CH ₄ emission factor for the livestock group
<i>EF2</i>		kg CH ₄ /head/yr	Manure management CH ₄ emission factor for the livestock group
<i>EF3</i>		kg N ₂ O-N/(kg N)/head/yr	Emission factor for N ₂ O emissions from manure management for the livestock group
<i>EF4</i>		kg N ₂ O-N/(kg NH ₃ -N and NO _x -N emitted)/head/yr	Emission factor for N ₂ O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces
<i>DBI</i>		kg d.m./head/day	Daily biomass intake
<i>Nex</i>		kg N/head/yr	Annual average N excretion per livestock head
<i>Fracgas</i>		kg NH ₃ -N and NO _x -N emitted/(kg N)	Fraction of managed livestock manure nitrogen that volatilizes as NH ₃ and NO _x in the manure management phase

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 60, where only significant sources must be reported.

Table 60: Ex Ante Estimated Total Emissions Above the Baseline from Leakage Prevention Activities

Project year t	Carbon 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
	$\Delta CLPMLK_t$	$\Delta CLPMLK$	$EgLK_t$	$EgLK$	$ELPMLK_t$	$ELPMLK$
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0						
1						
2						
...						
T						

8.3.1.2 Ex Ante Estimation of Decreases in Carbon Stocks and Increases in GHG emissions due to Activity Displacement Leakage

Activities that will cause deforestation within the project area in the baseline case may be displaced outside the project boundary due to implementation of the AUD project activity. Where carbon stocks in the leakage belt will decrease more during project implementation than projected in the baseline case, this indicates that leakage due to displacement of baseline activities has occurred. Leakage due to activity displacement may 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 must be established for the leakage belt following methods described in previous sections.

Do the ex ante baseline assessment of the leakage belt and report the result in Table 37 (where Method 1 is used) or Table 40 (where Method 2 is used).

Ex ante, activity displacement leakage may only be approximated based on the anticipated combined effectiveness of the proposed leakage prevention measures and project activities.

This must be done by multiplying the estimated baseline carbon stock changes for the project area by a Displacement Leakage Factor (DLF) representing the percentage of deforestation expected to be displaced outside the project boundary. Where deforestation agents do not participate in leakage prevention activities and project activities, the DLF is 100 percent. Where leakage prevention activities are implemented the factor is equal to the proportion of baseline agents estimated to be given the opportunity to participate in leakage prevention activities and project activities.

Where emissions from forest fires have been included in the baseline, ex ante emissions from forest fires due to activity displacement leakage are 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 61.

Table 61: Ex Ante Estimated Leakage due to Activity Displacement

Project year t	Total Ex Ante <i>Estimated</i> Decrease in Carbon Stocks due to Displaced Deforestation		Total Ex Ante <i>Estimated</i> Increase in GHG Emissions due to Displaced Forest Fires	
	Annual	Cumulative	Annual	Cumulative
	$\Delta CADLK_t$	$\Delta CADLK$	$EADLK_t$	$EADLK$
	t CO ₂ e	t CO ₂ e	t CO ₂ e	t CO ₂ e
0				
1				
2				
...				
T				

8.3.2 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-approved) program. In such cases, the most recent VCS JNR Requirements must 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) Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention activities (Section 8.3.2.1)
- 2) Decrease in carbon stocks and increase in GHG emissions due to activity displacement leakage (Section 8.3.2.2)

8.3.2.1 Monitoring of Carbon Stock Changes and GHG Emissions Associated With Leakage Prevention Activities

Monitoring of the sources of emissions associated with leakage prevention activities must follow the methods and tools described in Section 8.3.1.1.

Results must be reported using the same formats and tables used in the ex ante assessment:

Table 56	Ex post carbon stock change in leakage management zones
Table 57	Ex post net carbon stock change in leakage management zones ⁴²
Table 58	Ex post parameters for estimating GHG emissions from grazing activities
Table 59	Ex post estimation of emissions from grazing animals in leakage management zones
Table 60	Ex post estimation of net carbon stock changes and GHG emissions from leakage prevention activities

8.3.2.2 Monitoring of Carbon Stock Decreases and Increases in GHG Emissions due to Activity Displacement Leakage

Monitoring of Carbon Stock Changes

Deforestation above the baseline in the leakage belt area is considered activity displacement leakage.

⁴² Calculations of total net carbon stock changes in leakage management zones use the ex ante estimated baseline carbon stock changes in the leakage management zone and the measured ex post carbon stock changes. Where the cumulative value of the carbon stock change within a baseline validity period is greater than zero, $DCLPMLK_t$ is set to zero.

Activity data for the leakage belt must be determined using the same methods applied to monitoring deforestation activity data in the project area. Monitoring of categories II and III (Table 50) outside the project area is not required because credits are not 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 37 Ex post total net carbon stock changes in the leakage belt (Method 1)

OR

Table 40 Ex post total net carbon stock changes in the leakage belt (Method 2)

Leakage is calculated as the difference between the ex ante and ex post assessments. Report the results in Table 63.

Table 63: Total Net Baseline Carbon Stock Change in the Leakage Belt (Method 1)

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
	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0						
1						
2						
...						
T						

Where strong evidence is 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 nor considered leakage. The VVB must 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 Increases in GHG Emissions

These must only be estimated and accounted where emissions from forest fires are included in the baseline.

To estimate increased GHG emissions due to forest fires in the leakage belt, it is assumed that forest is cleared using fire. The parameter values used to estimate emissions must be the same as those used to estimate forest fires in the baseline (Table 41), except for the initial carbon stocks (C_{ab} , C_{dw}) which must be those of the initial forest classes burned in the leakage belt.

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 41 Parameters used to calculate emissions from forest fires in the leakage belt

Table 42 Ex post estimated non-CO₂ emissions from forest fires in the leakage belt

8.3.2.3 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 62 Total ex post estimated leakage

Note – monitoring of leakage may become obsolete at the date on which a VCS or UNFCCC registered (and VCS-approved) program is monitoring, reporting, verifying and accounting GHG emissions from deforestation in a broader region encompassing the project area. In such cases, requirements in the most recent version of the VCS Standard must be applied.

8.4 Estimated GHG Emission Reductions

8.4.1 Ex Ante Total Net GHG Emission Reductions (Step 9)

8.4.1.1 Significance Assessment

All carbon pools and sources of GHG emissions considered in this methodology must be calculated to assess their significance. Use Appendix 2 to determine the significance of each of the ex ante calculated carbon stock changes and GHG emissions. Report the result of this analysis in the PD.

Only significant sources and pools need to be accounted in the calculation of net anthropogenic GHG emission reductions (Section 8.4.1.2) and only significant sources and pools must be considered in the monitoring plan.

8.4.1.2 Calculation of Ex Ante Total Net GHG Emissions Reductions

The net anthropogenic GHG emission reduction of the proposed AUD project activity is calculated as follows:

$$\Delta REDD_t = (\Delta C_{BSLPA}_t + E_{BBBSLPA}_t) - (\Delta C_{PSPA}_t + E_{BBPSPA}_t) - (\Delta CLK_t + ELK_t) \quad (19)$$

Where:

$$\begin{aligned} \Delta REDD_t &= \text{Ex ante estimated net anthropogenic GHG emission reduction} \\ &\text{attributable to the AUD project activity at year } t \text{ (t CO}_2\text{e)} \\ \Delta CBSLPA_t &= \text{Sum of baseline carbon stock changes in the project area at year } t \\ &\text{(t CO}_2\text{e)} \end{aligned}$$

Note – the absolute values of $\Delta CBSLPA_t$ must be used in Eq. (19).

$$\begin{aligned} EBBBSLPA_t &= \text{Sum of baseline emissions from biomass burning in the project area at} \\ &\text{year } t \text{ (t CO}_2\text{e)} \\ \Delta CPSPA_t &= \text{Sum of ex ante estimated actual carbon stock changes in the project} \\ &\text{area at year } t \text{ (t CO}_2\text{e)} \end{aligned}$$

Note – where $\Delta CPSPA_t$ represents a net increase in carbon stocks, a negative sign before the absolute value of $\Delta CPSPA_t$ must be used. Where $\Delta CPSPA_t$ represents a net decrease, a positive sign must be used.

$$\begin{aligned} EBBPSPA_t &= \text{Sum of (ex ante estimated) actual emissions from biomass burning in} \\ &\text{the project area at year } t \text{ (t CO}_2\text{e)} \\ \Delta CLK_t &= \text{Sum of ex ante estimated leakage net carbon stock changes at year } t \\ &\text{(t CO}_2\text{e)} \end{aligned}$$

Note – where the cumulative sum of ΔCLK_t within a baseline validity period is greater than zero, ΔCLK_t must be set to zero.

$$\begin{aligned} ELK_t &= \text{Sum of ex ante estimated leakage emissions at year } t \text{ (t CO}_2\text{e)} \\ t &= 1, 2, 3, \dots, T, \text{ a year of the proposed project crediting period} \\ &\text{(dimensionless)} \end{aligned}$$

8.4.1.3 Calculation of Ex-Ante Verified Carbon Units (VCUs)

The potential number of Verified Carbon Units (VCUs) at year t is estimated as follows:

$$VCU_t = \Delta REDD_t - VBC_t \quad (20)$$

$$VBC_t = (\Delta CBSLPA_t - \Delta CPSPA_t) \times RF_t \quad (21)$$

Where:

$$VCU_t = \text{Number of potential Verified Carbon Units at year } t \text{ (t CO}_2\text{e)}$$

Note – where VCU_t is less than zero, no VCUs will be granted to the proponents of the AUD project activity. VCUs are only granted where the following condition is met:

$$\sum_{t=0}^t \Delta REDD_t > 0 \quad (22)$$

$$\Delta REDD_t = \text{Ex ante estimated net anthropogenic GHG emission reductions} \\ \text{attributable to the AUD project activity at year } t \text{ (t CO}_2\text{e/ha)}$$

VBC_t	=	Number of buffer credits deposited in the VCS AFOLU non-permanence buffer at year t (t CO ₂ e)
ΔC_{BSLPA}_t	=	Sum of baseline carbon stock changes in the project area at year t (t CO ₂ e)
ΔC_{PSPA}_t	=	Sum of ex ante estimated actual carbon stock changes in the project area at year t (t CO ₂ e/ha)
RF_t	=	Risk factor used to calculate buffer credits (%)

Note – RF_t is a risk factor to be determined using the latest version of the VCS AFOLU Non-Permanence Risk Tool.

t	=	1, 2, 3, ..., T , a year of the proposed project crediting period (dimensionless)
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Present the result of the calculations in Table 64.

Table 64: Ex Ante Estimated Net GHG Emission Reductions: ($\Delta REDD_t$) and Verified 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	Cum	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	$\Delta CBSLP_{A_t}$	$\Delta CBSLP_A$	$EBBBSL_{PA_t}$	$EBBBSL_{PA}$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EBBPSP_{A_t}$	$EBBPSP_A$	ΔCLK_t	ΔCLK	ELK_t	ELK	$\Delta REDD_t$	$\Delta REDD$	VCU_t	VCU	VBC_t	VBC
	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}	t CO _{2e}
0																		
1																		
2																		
...																		
T																		

8.4.2 Ex Post Net GHG Emission Reductions

The calculation of ex post net GHG emission reductions is similar to the ex 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 as that used for the ex ante assessment:

Table 64 Ex post estimated net anthropogenic GHG emission reductions and VCUs

Note – a map showing Cumulative Areas Credited within the project area must be updated and presented to the VVB at each verification. The cumulative area must not generate additional VCUs in future periods.

9 MONITORING

9.1 Data and Parameters

Table 65: Data and Parameters

Notation	Description	Unit	Observation	Source	Monitoring
$\pm 90\%$ CI	90% confidence interval				
A	Area in which observed change is incorrectly predicted as persistence (ha)	ha		Calculated	Each renewal of baseline validity period
a	Estimated intercept of the regression line	ha/yr		Calculated	Each renewal of baseline validity period
a_1 and a_2	Sample plot areas	ha		Calculated	Each renewal of baseline validity period
$A_{average_i}$	Area of “average” forest land suitable for conversion to non-forest land within stratum	ha		Calculated	Each renewal of baseline validity period
$ABSLLK$	Cumulative area of baseline deforestation within the leakage belt at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLLK_{ct,t}$	Area of category ct deforested at time t within the leakage belt in the baseline case	ha		Measured or estimated from literature	Each renewal of baseline validity period
$ABSLLK_{fcl,t}$	Area of final (post-deforestation) forest class fcl deforested at time t within the leakage belt in the baseline case	ha		Calculated	Each renewal of baseline validity period
$ABSLLK_{i,t}$	Annual area of baseline deforestation in stratum i within the leakage belt at year t	ha		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
$ABSLK_{icl,t}$	Area of initial (pre-deforestation) forest class icl deforested at time t within the leakage belt in the baseline case	ha		Calculated	Each renewal of baseline validity period
$ABSLK_t$	Annual area of baseline deforestation within the leakage belt at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLPA$	Cumulative area of baseline deforestation in the project area at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLPA_{ct,t}$	Area of category ct deforested at time t within the project area in the baseline case	ha		Measured or estimated from literature	Each renewal of baseline validity period
$ABSLPA_{i,t}$	Annual area of baseline deforestation in stratum i within the project area at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLPA_{icl,t}$	Area of initial (pre-deforestation) forest class icl deforested at time t within the project area in the baseline case	ha		Calculated	Each renewal of baseline validity period
$ABSLPA_t$	Annual area of baseline deforestation in the project area at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLPA_{z,t}$	Area of zone z deforested at time t within the project area in the baseline case	ha		Calculated	Each renewal of baseline validity period
$ABSLRR$	Cumulative area of baseline deforestation in the reference region at year t	ha		Calculated	Each renewal of baseline validity period
$ABSLRR_{ct,t}$	Area of category ct deforested at time t within the reference region in the baseline case	ha		Measured or estimated from literature	Each renewal of baseline validity period
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum i within the reference region at year t	ha		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
$ABSLRR_{taverage,i}$	Annual area of baseline deforestation in stratum i within the reference region at year t average $_i$	ha		Calculated	Each renewal of baseline validity period
$ABSLRR_t$	Annual area of baseline deforestation in the reference region at year t	ha		Calculated	Each renewal of baseline validity period
$ACPA_{icl,t}$	Annual area within the project area affected by catastrophic events in class icl at year t	ha		Measured ex post	Each time a catastrophic event occurs
$Aforage_t$	Area under forage above the baseline in leakage management zones	ha		Calculated ex ante, measured ex post	Annually
$Aoptimal_i$	Area of optimal forest land suitable for conversion to non-forest land within stratum i	ha		Calculated	Each renewal of baseline validity period
AP	Plot area	m ²		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
$APFPA_{icl,t}$	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

Notation	Description	Unit	Observation	Source	Monitoring
$APSLK_{fcl,t}$	Annual area of class fcl with decreasing carbon stock in leakage management zones in the project case at year t	ha		Measured ex post	Annually
ARR_i	Total forest area in stratum i within the reference region at the project start date	ha		Measured or estimated from literature	Each renewal of baseline validity period
$ARR_{i,t-1}$	Area with forest cover in stratum i within the reference region at year $t - 1$	ha		Calculated	Each renewal of baseline validity period
$AUFPA_{icl,t}$	Areas affected by forest fires in class icl in which carbon stock recovery occurs at year t	ha		Measured ex post	Annually
B	Area in which observed change is correctly predicted as actual change	ha		Measured or estimated from literature	Each renewal of baseline validity period
b	Estimated coefficient of the time variable (or slope of the linear regression)	dimensionless		Calculated	Each renewal of baseline validity period
$BCEF$	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass	dimensionless		Measured or estimated from literature	Only once at project start
BEF_{pl}	Biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark), applicable to tree tr , in plot pl	dimensionless		Measured or estimated from literature	Only once at project start
$BLDA, BLDB, \dots BLDN$	Total area of projected baseline deforestation during the baseline validity period of Project A	ha		PD of project A; PD of project B, ... PD of Project N	Each renewal of baseline validity period
C	Area in which observed persistence is incorrectly predicted as change	ha		Calculated	

Notation	Description	Unit	Observation	Source	Monitoring
Cab_{fcl}	Average carbon stock per hectare in aboveground biomass carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	
Cab_{cl}	Average carbon stock per hectare in aboveground biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cab_{icl}	Average carbon stock per hectare in aboveground biomass carbon pool of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	
$Cabnt_{cl}$	Average carbon stock per hectare in aboveground non-tree biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$Cabt_{cl}$	Average carbon stock per hectare in aboveground tree biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$Cabz$	Average carbon stock per hectare in aboveground biomass carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Ca_{cl}	Average carbon stock per hectare in aboveground biomass in LU/LC class cl	t CO ₂ e/ha			
Cbb_{cl}	Average carbon stock per hectare in belowground biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cbb_{fcl}	Average carbon stock per hectare in belowground biomass carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	

Notation	Description	Unit	Observation	Source	Monitoring
Cbb_{icl}	Average carbon stock per hectare in belowground biomass carbon pool of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	
$Cbbnt_{cl}$	Average carbon stock per hectare in belowground non-tree biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cbb_{fcl}	Average carbon stock per hectare in belowground biomass carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	
$Cbbt_{cl}$	Average carbon stock per hectare in belowground tree biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cbb_z	Average carbon stock per hectare in belowground tree biomass carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cdw_{fcl}	Average carbon stock per hectare in dead wood biomass carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cdw_{cl}	Average carbon stock per hectare in dead wood biomass carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cdw_{icl}	Average carbon stock per hectare in dead wood biomass carbon pool of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	
Cdw_z	Average carbon stock per hectare in dead wood biomass carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$CE_{p,icl}$	Average combustion efficiency of carbon pool p in initial forest class icl	dimensionless		Measured or estimated from literature	Only once at project start

Notation	Description	Unit	Observation	Source	Monitoring
CF_{dc}	Carbon fraction of density class dc	t C/t d.m.		Measured or estimated from literature	Only once at project start and where mandatory
CF_j	Carbon fraction for tree tr , of species, group of species or forest type j	t C/t d.m.		Measured or estimated from literature	Only once at project start
CF_{pl}	Carbon fraction of sample pl	t C/t d.m.		Calculated	Only once at project start and where mandatory
C_i	Cost to select and measure a plot of LU/LC class cl			Estimated	Each renewal of baseline validity period
cl	1, 2, 3, ..., Cl LU/LC classes	dimensionless		Measured or estimated from literature	Each renewal of baseline validity period
Clw_{fcl}	Average carbon stock per hectare in lying dead wood carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	
Cl_{cl}	Average carbon stock per hectare in litter carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Clw_{cl}	Average carbon stock per hectare in lying dead wood carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Clw_{icl}	Average carbon stock per hectare in lying dead wood carbon pool of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	
Cl_{fcl}	Average carbon stock per hectare in litter carbon pool of LU/LC class fcl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
Cl_{icl}	Average carbon stock per hectare in litter carbon pool of LU/LC class icl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
C_{Iz}	Average carbon stock per hectare in litter carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
C_p	Average carbon stock per hectare in carbon pool p	t CO ₂ e/ha		Calculated	Only once at project start
$C_{p_{icl,t}}$	Average carbon stock per hectare in carbon pool p burned at year t in forest class icl	t CO ₂ e/ha		Calculated	Only once at project start
$C_{SOC_{fcl}}$	Average carbon stock per hectare in soil organic carbon pool of final post-deforestation class fcl	t CO ₂ e/ha		Measured or estimated from literature	
C_{SOC_z}	Average carbon stock per hectare in soil organic carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$C_{sdw_{cl}}$	Average carbon stock per hectare in standing dead wood carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$C_{SOC_{icl}}$	Average carbon stock per hectare in soil organic carbon pool of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$C_{SOC_{cl}}$	Average carbon stock per hectare in soil organic carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
C_{SOC_p}	Carbon stock per hectare in soil organic carbon pool estimated for plot p	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start
ct	1, 2, 3, ..., C_t categories of LU/LC change (from initial forest classes icl to final post-deforestation classes fcl)	dimensionless		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
$C_{tot_{cl}}$	Average carbon stock per hectare in all accounted carbon pools of LU/LC class cl	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$C_{tot_{fcl,t}}$	Average carbon stock of all accounted carbon pools in non-forest class fcl at time t	t CO ₂ e/ha		Calculated	Only once at project start
$C_{tot_{icl}}$	Average carbon stock of all accounted carbon pools in forest class icl	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$C_{tot_{icl,t}}$	Average carbon stock of all accounted carbon pools in forest class icl at time t	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
C_{tot_z}	Average carbon stock of all accounted carbon pools per zone z	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
ctz	1, 2, 3, ..., Ctz categories of LU/LC change (from initial forest classes icl to post deforestation zones z)	dimensionless		Calculated	Each renewal of baseline validity period
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	%		Literature	Only once at project start and where mandatory
$C_{wp_{fcl}}$	Average carbon stock per hectare in harvested wood products carbon pool of final post-deforestation class fcl	t CO ₂ e/ha			Only once at project start and where mandatory
$C_{wp_{cl}}$	Average carbon stock per hectare in harvested wood products carbon pool of LU/LC class cl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
CWP_{icl}	Average carbon stock per hectare in harvested wood products carbon pool of initial forest class icl	t CO ₂ e/ha			Only once at project start and where mandatory
$CWP_{lt,icl,t}$	Carbon stock in long-term wood products carbon pool at time of deforestation t of initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
$CWP_{mt,icl,t}$	Carbon stock in medium-term wood products carbon pool at time of deforestation t of the initial forest class icl	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where mandatory
CWP_z	Average carbon stock per hectare in harvested wood products carbon pool per zone z	t CO ₂ e/ha		Measured or estimated from literature	Only once at project start and where 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		Measured or estimated from literature	Only once at project start and where mandatory
$d1, d2, \dots, dn$	Diameters of intersecting pieces of dead wood	cm		Measured or estimated from literature	Only once at project start and where mandatory
DBH	Diameter at breast height	cm		Measured or estimated from literature	Only once at project start and where mandatory
DBI	Daily biomass intake	kg d.m./head/day		Measured or estimated from literature	Each renewal of baseline validity period
dc	1, 2, 3 dead wood density classes	dimensionless		Defined	
DC	Total number of density classes (3)	dimensionless		Defined	
ΔCab_{ct}	Average emission factor in aboveground biomass carbon pool of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
$\Delta CabBSLLK_t$	Total baseline carbon stock changes for aboveground biomass pool in leakage belt	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CabBSLLK_t$	Cumulative baseline carbon stock changes for aboveground biomass pool in leakage belt	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CabBSLPA$	Cumulative baseline carbon stock changes for aboveground biomass pool in project area	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CabBSLPA_t$	Total baseline carbon stock changes for aboveground biomass pool in project area	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CabBSLRR$	Cumulative baseline carbon stock changes for aboveground biomass pool in reference region	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CabBSLRR_t$	Total baseline carbon stock changes for aboveground biomass pool in reference region	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CADLK$	Cumulative total decrease in carbon stocks due to displaced deforestation	t CO ₂ e		Calculated	Annually
$\Delta CADLK_t$	Total decrease in carbon stocks due to displaced deforestation at year <i>t</i>	t CO ₂ e		Calculated	Annually
ΔCbb_{ct}	Average emission factor in belowground biomass carbon pool of category <i>ct</i>	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta CBSLPA_{ft}$	Total baseline carbon stock change in final classes within project area at year <i>t</i>	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA$	Total baseline carbon stock changes in project area	t CO ₂ e		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
$ABSLPA_{ct,t}$	Area of category ct deforested at time t within project area in baseline case	ha		Calculated	Each renewal of baseline validity period
$\Delta CBSLLK$	Cumulative carbon stock changes in leakage management zones in baseline case	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLLK_t$	Annual carbon stock changes in leakage management zones in baseline case at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA_f$	Total cumulative baseline carbon stock change in final classes within project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA_{ft}$	Total annual baseline carbon stock change in final classes within project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA$	Total net cumulative baseline carbon stock change in final classes within project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA_i$	Total cumulative baseline carbon stock change in initial forest classes within project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA_{it}$	Total baseline carbon stock change in initial forest classes within the project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSLPA_t$	Total baseline carbon stock change within project area at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CBSL_t$	Total baseline carbon stock change at year t in project area	t CO ₂ e		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
ΔCdw_{ct}	Average emission factor in dead wood biomass carbon pool of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta CFCdPA$	Cumulative decrease in carbon stock due to forest fires and catastrophic events at year t in project area	t CO ₂ e	Ex post	Calculated	
$\Delta CFCdPA_t$	Total decrease in carbon stock due to forest fires and catastrophic events at year t in project area	t CO ₂ e	Ex post	Calculated	Annually
$\Delta CFCiPA$	Cumulative increase in carbon stock due to forest fires and catastrophic events at year t in 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 project area	t CO ₂ e	Ex post	Calculated	Annually
ΔCl_{ct}	Average emission factor in litter carbon pool of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
ΔCLK	Total cumulative decrease in carbon stocks within leakage belt at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
ΔCLK_t	Total decrease in carbon stocks within leakage belt at year t	t CO ₂ e		Calculated	Each renewal of baseline validity period
$\Delta CLPMLK$	Cumulative carbon stock decrease due to leakage prevention measures	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CLPMLK_t$	Carbon stock decrease due to leakage prevention measures at year t	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCp_t	Emission factor applicable to pool p at time t	t CO ₂ e		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
ΔCPA_{dPA}	Cumulative decrease in carbon stock due to all planned activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPA_{dPA_t}	Total decrease in carbon stock due to all planned activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPA_{iPA}	Cumulative increase in carbon stock due to all planned activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPA_{iPA_t}	Total increase in carbon stock due to all planned activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPD_{dPA}	Cumulative decrease in carbon stock due to planned deforestation at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPD_{dPA_t}	Total decrease in carbon stock due to planned deforestation at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPF_{dPA}	Cumulative decrease in carbon stock due to planned fuel-wood and charcoal activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPF_{dPA_t}	Total decrease in carbon stock due to planned fuel-wood and charcoal activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPF_{iPA}	Cumulative increase in carbon stock due to planned fuel-wood and charcoal activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ΔCPF_{iPA_t}	Total increase in carbon stock due to planned fuel-wood and charcoal activities at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually

Notation	Description	Unit	Observation	Source	Monitoring
$\Delta C_{p icl,t=t^*}$	Average emission factor for carbon pool p in initial forest class icl applicable at time t	t CO ₂ e/ha			
$\Delta CPLdPA$	Cumulative decrease in carbon stock due to planned logging activities at year t in 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 project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CPLiPA$	Cumulative increase in carbon stock due to planned logging activities at year t in 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 project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CPNiPA$	Cumulative increase in carbon stock due to planned protection of growing forest classes in project area at year t	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 project area at year t	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CPSLK$	Total cumulative carbon stock change in leakage management zones in project case	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CPSLK_t$	Total annual carbon stock change in leakage management zones in project case	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CPSPA$	Cumulative project carbon stock change within 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 project area at year t	t CO ₂ e	Ex ante and ex post	Calculated	Annually

Notation	Description	Unit	Observation	Source	Monitoring
$\Delta C_{p,z,t=t^*}$	Average emission factor for carbon pool p in zone z applicable at time $t = t^*$	t CO ₂ e/ha		Calculated	Each renewal of baseline validity period
$\Delta C_{soc_{ct}}$	Average emission factor in soil organic carbon pool of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta C_{tot_{ct,t}}$	Emission factor for all accounted carbon pools in category ct at time t	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta C_{tot_{ct}}$	Average emission factor in all accounted carbon pools of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta C_{tot_{icl,t}}$	Average carbon stock change of all accounted carbon pools in forest class icl at time t	t CO ₂ e/ha		Calculated	Each renewal of baseline validity period
$\Delta CUCdPA$	Cumulative decrease in carbon stock due to catastrophic events at year t in project area	t CO ₂ e	Ex post	Calculated	Annually
$\Delta CUCdPA_t$	Total decrease in carbon stock due to catastrophic events at year t in project area	t CO ₂ e	Ex post	Calculated	Annually
$\Delta CUCiPA$	Cumulative increase in carbon stock in areas affected by catastrophic events (after such events) at year t in 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 project area	t CO ₂ e	Ex post	Calculated	Annually
$\Delta CUDdPA$	Cumulative actual carbon stock change due to unavioded unplanned deforestation at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually

Notation	Description	Unit	Observation	Source	Monitoring
$\Delta CUDdPA_t$	Total actual carbon stock change due to unavoided unplanned deforestation at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta CUFdPA$	Cumulative total decrease in carbon stock due to unplanned (and planned where applicable) forest fires in project area	t CO ₂ e	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 project area	t CO ₂ e	Ex post	Calculated	Annually
$\Delta CUFiPA$	Cumulative increase in carbon stock in areas affected by forest fires (after such events) in 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 project area	t CO ₂ e	Ex post	Calculated	Annually
ΔCwp_{ct}	Average emission factor in harvested wood products carbon pool of category ct	t CO ₂ e/ha		Calculated	Only once at project start and where mandatory
$\Delta REDD$	Cumulative net anthropogenic GHG emission reduction attributable to AUD project activity	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$\Delta REDD_t$	Net anthropogenic GHG emission reduction attributable to AUD project activity at year t	t CO ₂ e	Ex ante and ex post	Calculated	Annually
D_{dc}	Dead wood density of class dc	t d.m./m ³		Measured or estimated from literature	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
D_j	Mean wood density of species j	t d.m./m ³		Measured or estimated from literature	Only once at project start
DLF	Displacement leakage factor	%		Defined	Each renewal of baseline validity period
Dm	Deadwood density	g/cm ³		Measured or estimated from literature	Only once at project start and where mandatory
DM_{pl}	Dry mass of sample pl	t d.m.		Measured or estimated from literature	Only once at project start and where mandatory
e	Euler's number (2.71828)	dimensionless			
$E\%$	Allowable sample error in percentage ($\pm 10\%$)	%			
E	Allowable error ($\pm 10\%$ of the mean)	%			
$EADLK$	Cumulative total increase in GHG emissions due to displaced forest fires	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EADLK_t$	Total ex ante increase in GHG emissions due to displaced forest fires at year t	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBBSPA$	Cumulative baseline non-CO ₂ emissions from forest fires at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBBSLPA_t$	Sum of (or total) baseline non-CO ₂ emissions from forest fires at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually

Notation	Description	Unit	Observation	Source	Monitoring
$EBBBSL_{tot_{icl}}$	Sum of (or total) actual non-CO ₂ emissions from forest fires at year t in stratum i in forest class icl	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBCH_{4_{icl}}$	CH ₄ emissions from biomass burning in forest class icl	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBCO_{2_{icl}}$	Per hectare CO ₂ emissions from biomass burning in slash and burn in forest class icl	t CO ₂ e/ha		Calculated	Only once at project start
$EBBN_{2O_{icl}}$	N ₂ O emissions from biomass burning in forest class icl	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBPSPA$	Cumulative (or total) actual non-CO ₂ emissions from forest fires at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBBPSPA_t$	Sum of (or total) actual non-CO ₂ emissions from forest fires at year t in project area	t CO ₂ e	Ex ante and ex post	Calculated	Annually
$EBB_{tot_{icl}}$	Total GHG emission from biomass burning in forest class icl	t CO ₂ e	Ex ante and ex post	Calculated	Annually
ECH_{4ferm_t}	CH ₄ emissions from enteric fermentation at year t	t CO ₂ e		Calculated	Annually
ECH_{4man_t}	CH ₄ emissions from manure management at year t	t CO ₂ e		Calculated	Annually
$EdirN_{2Oman_t}$	Direct N ₂ O emissions from manure management at year t	t CO ₂ e		Calculated	Annually
$EF1$	Enteric CH ₄ emission factor for livestock group	kg CH ₄ /head/yr		Calculated	Each renewal of baseline validity period
$EF2$	Manure management CH ₄ emission factor for livestock group	kg CH ₄ /head/yr		Measured or estimated from literature	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
<i>EF3</i>	Emission factor for N ₂ O emissions from manure management for livestock group	kg N ₂ O-N/kg N/head/yr		Measured or estimated from literature	Each renewal of baseline validity period
<i>EF4</i>	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/head/yr		Measured or estimated from literature	Each renewal of baseline validity period
<i>EgLK</i>	Cumulative emissions from grazing animals in leakage management zones at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>EgLK_t</i>	Emissions from grazing animals in leakage management zones at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>EI</i>	Ex ante estimated effectiveness index	%		Defined	Annually
<i>EindNOman_t</i>	Indirect N ₂ O emissions from manure management at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>ELK</i>	Cumulative sum of ex ante estimated leakage emissions at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>ELK_t</i>	Sum of ex ante estimated leakage emissions at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>ELPMLK</i>	Cumulative total ex ante increase in GHG emissions due to leakage prevention measures	t CO ₂ e		Calculated	Annually
<i>ELPMLK_t</i>	Annual total increase in GHG emissions due to leakage prevention measures at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>EN2Oman_t</i>	N ₂ O emissions from manure management at year <i>t</i>	t CO ₂ e		Calculated	Annually
<i>ERCH4</i>	Emission ratio for CH ₄ (IPCC default value = 0.012)	dimensionless		Defined	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
ERN_{2O}	Emission ratio for N_2O (IPCC default value = 0.007)	dimensionless		Defined	Each renewal of baseline validity period
$F_{burnt_{icl}}$	Proportion of forest area burned during historical reference period in forest class icl	%		Measured or estimated from literature	Only once at project start
f_{cl}	1, 2, 3, ..., F_{cl} final (post-deforestation) non-forest classes	dimensionless		Measured or estimated from literature	Each renewal of baseline validity period
$f_j(DBH, H)_{ab}$	Allometric equation for species, or group of species or forest type j , linking aboveground tree biomass (in kg/tree) to diameter at breast height (DBH) and possibly tree height (H)			Measured or estimated from literature	Only once at project start
FOM	Figure of merit	dimensionless	Measure of goodness of fit between observed and predicted deforestation	Calculated	Each renewal of baseline validity period
$Frac_{gas}$	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NO_x in manure management phase	kg NH_3 -N and NO_x -N emitted/kg N		Calculated	Each renewal of baseline validity period
$f_j(DBH, H)_v$	a commercial volume equation for species or species group j , linking commercial volume to diameter at breast height (DBH) and possibly tree height (H)			Calculated	Each renewal of baseline validity period
$f(t)$	Function of time			Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
GWP_{CH_4}	Global Warming Potential for CH ₄ (IPCC default value = 21 for first commitment period)	dimensionless		Defined	Each renewal of baseline validity period
GWP_{N_2O}	Global Warming Potential for N ₂ O (IPCC default value = 310 for first commitment period)	dimensionless		Defined	Each renewal of baseline validity period
H	Height of tree	meters		Measured or estimated from literature	Only once at project start and where mandatory
i	1, 2, 3, ..., I_{RR} stratum within reference region	dimensionless		Defined	Each renewal of baseline validity period
icl	1, 2, 3, ..., icl initial (pre-deforestation) forest classes	dimensionless		Measured or estimated from literature	Each renewal of baseline validity period
ID_{cl}	Land use/land cover class identifier				
ID_{ct}	Land use/land cover change category identifier (from initial class icl to final class fcl)				
ID_{ctz}	Land use/land cover change category identifier (from initial class icl to zone z)				
ID_{fcl}	Final post-deforestation class fcl identifier				
ID_i	Stratum i in reference region identifier				
ID_{icl}	Initial forest class icl identifier				
ID_z	Zone identifier				
j	Number of organic fertilizer types	dimensionless		Defined	Annually
k	Estimated parameter of logistic regression	dimensionless		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
L	Length of line	m		Measured or estimated from literature	Only once at project start and where mandatory
$LTFw$	Fraction of wood products that are considered permanent (i.e., carbon is stored for 100 years or more) and from which it may be assumed that no carbon is released				
$\%LKB$	Percentage of overlapping leakage belt area to be assigned to projects A, B, ..., N	%		Calculated	At each verification
$MTFw$	Fraction of wood products that are retired between 3 and 100 years				
n	Total number of sample units to be measured (in all LU/LC classes)	dimensionless		Calculated	Each renewal of baseline validity period
N	Population size or maximum number of possible sample units (all LU/LC classes)	dimensionless		Measured	Each renewal of baseline validity period
n_{cl}	Number of samples units to be measured in LU/LC class c_l that is allocated in proportion to $W_{cl} \times S_{cl} / \sqrt{C_{cl}}$.	dimensionless			Each renewal of baseline validity period
NCR	Nitrogen to carbon ratio (IPCC default value = 0.01)	dimensionless		Defined	Each renewal of baseline validity period
Nex	Annual average N excretion per livestock head	kg N/head/yr		Measured or estimated from literature	Each renewal of baseline validity period
n_i	Number of sample units to be measured in LU/LC class c_l that is allocated in proportion to class size. Where estimated $n_{cl} < 3$, set $n_{cl} = 3$				

Notation	Description	Unit	Observation	Source	Monitoring
N_i	Maximum number of possible sample units for LU/LC class cl , calculated by dividing area of class cl by measurement plot area				
OFw	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years following timber harvest	dimensionless		Measured or estimated from literature	Only once at project start
p	Combustible carbon pool (aboveground biomass, dead wood, litter)	dimensionless		Defined	Each renewal of baseline validity period
$Pburnt_{p,icl}$	Average proportion of mass burned in carbon pool p in forest class icl	%		Measured or estimated from literature	Only once at project start
$PCab_{pl}$	Carbon stock in aboveground biomass in plot pl	t C/ha		Calculated	Only once at project start and where mandatory
$PCbb_{pl}$	Carbon stock in belowground biomass in plot pl	t C/ha		Calculated	Only once at project start and where mandatory
$Pcom_{icl}$	Commercial volume as a percentage of total aboveground volume in initial forest class icl	dimensionless		Measured or estimated from literature	Only once at project start and where mandatory
PCx_i	Average in situ production costs for one tonne of product Px in stratum i	\$/t	May have different values within different reference region strata	Measured or estimated from literature	Each renewal of baseline validity period
$Pforage_t$	Production of forage at year t	kg d.m./yr		Calculated ex ante, measured ex post	Each renewal of baseline validity period
pl	1, 2, 3, ..., $PLcl$ plots in LU/LC class cl	dimensionless		Calculated	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
PL_{cl}	Total number of plots in LU/LC class cl	dimensionless		Calculated	Only once at project start and where mandatory
P_o	Anhydrous weight of sample	g		Measured or estimated from literature	Only once at project start and where mandatory
$Population_t$	Equivalent number of forage-fed livestock at year t	number of heads		Calculated ex ante, measured ex post	Annually
$PP_{i,t}$	Proportion of stratum i within project area at time t	%		Calculated	Each renewal of baseline validity period
PPX_l	Potential profitability of product Px at location l (pixel or polygon)	\$/t		Calculated	Each renewal of baseline validity period
P_s	Saturated weight of sample	g		Measured or estimated from literature	Only once at project start and where mandatory
P_x	Product x produced in reference region	dimensionless		Measured or estimated from literature	Each renewal of baseline validity period
r_1	Radius at base of tree	meters		Measured or estimated from literature	Only once at project start and where mandatory
r_2	Radius at top of tree	meters		Measured or estimated from literature	Only once at project start and where mandatory
$RBSLRR_{i,t}$	Percentage of remaining forest area at year $t - 1$ in stratum i to be deforested at year t	%	Used as an alternative to $ABSLRR_{i,t}$ in baseline approach c	Calculated	Each renewal of baseline validity period
RF_t	Risk factor used to calculate VCS buffer credits	%		Estimated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
R_j	Root to shoot ratio appropriate for species, group of species or forest type j	dimensionless		Measured or estimated from literature	Only once at project start
$R_{j,pl,tr}$	Root to shoot ratio, applicable to tree tr of species j in plot pl	dimensionless		Measured or estimated from literature	Only once at project start
S_{cl}	Standard deviation of LU/LC class cl				
$S\$_x$	Selling price of product P_x	\$/t		Measured or estimated from literature	Each renewal of baseline validity period
SLF_w	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	dimensionless		Measured or estimated from literature	Only once at project start
SP_{Xl}	Sale location l of product P_x	map		Measured or estimated from literature	Each renewal of baseline validity period
STF_w	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years – all carbon must be assumed to be lost immediately	dimensionless			
t	1, 2, 3, ..., T a year of the proposed project crediting period	dimensionless		Defined	
t^*	year at which area $ABSLPA_{icl,t}$ is deforested in the baseline case	dimensionless		Defined	
$t1$	Start date of historical reference period	dimensionless			
$t2$	End date of historical reference period	dimensionless			
$T_{average_i}$	Number of years in which $A_{average_i}$ is deforested in baseline case	yr		Calculated	Each renewal of baseline validity period

Notation	Description	Unit	Observation	Source	Monitoring
$T_{average_i}$	Year at which $T_{average_i}$ ends	yr		Calculated	Each renewal of baseline validity period
T_{Bab_j}	Aboveground biomass of a tree of species, species group or forest type j	kg/tree or t/tree		Calculated	Only once at project start
$T_{Bab_{tr}}$	Aboveground biomass of tree tr	kg/tree or t/tree		Calculated	Only once at project start
$T_{Cab_{tr}}$	Carbon stock in aboveground biomass of tree tr	kg C/tree or t C/tree		Calculated	Only once at project start
$T_{Cbb_{tr}}$	Carbon stock in belowground biomass of tree tr	kg C/tree		Calculated	Only once at project start and where mandatory
T_{Cv}	Average transport cost per kilometer for one tonne of product P_x on land, river or road of type v	\$/t/km		Measured or estimated from literature	Each renewal of baseline validity period
T_{Dv}	Transport distance on land, river or road of type v	km		Calculated	Each renewal of baseline validity period
$Thrp$	Duration of historical reference period	yr		Defined	
$T_{optimal_i}$	Number of years since start of AUD project activity in which $A_{optimal}$ in stratum i is deforested in the baseline case	yr		Calculated	Each renewal of baseline validity period
$t_{optimal_i}$	Year at which $T_{optimal_i}$ ends	yr		Calculated	Each renewal of baseline validity period
tr	1, 2, 3, ..., $TRpl$ number of trees in plot pl	dimensionless		Measured or estimated from literature	Only once at project start and where mandatory
t_{st}	t student value for a 95% confidence level (initial value $t = 2$)	dimensionless			

Notation	Description	Unit	Observation	Source	Monitoring
$T_{sub-optimal_i}$	Number of years in which $A_{sub-optimal_i}$ is deforested in the baseline case	yr		Calculated	Each renewal of baseline validity period
v	1,2,3, ..., V type of surface on which transport occurs	dimensionless		Measured or estimated from literature	Each renewal of baseline validity period
$V1_{i,t}, V2_{i,t}, \dots, Vn_{i,t}$	Variables included in deforestation model		Unit of each variable to be specified by project proponent	Measured or estimated from literature	Each renewal of baseline validity period
VBC_t	Number of buffer credits deposited in the VCS buffer pool at time t	t CO ₂ e		Calculated	Annually
VCU_t	Number of Verified Carbon Units (VCUs) to be made available for trade at time t	t CO ₂ e		Calculated	Annually
VEF	Volume expansion factor	dimensionless		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		Measured or estimated from literature	Only once at project start and where mandatory
$VOB10$	Volume over bark above 10 cm DBH	m ³		Measured or estimated from literature	Only once at project start
$VOB30$	Volume over bark above 30 cm DBH	m ³		Measured or estimated from literature	Only once at project start
$Volume_{dc}$	Volume of lying dead wood in density class dc	m ³		Measured or estimated from literature	Only once at project start and where mandatory

Notation	Description	Unit	Observation	Source	Monitoring
V_{pl}	Commercial volume of plot pl	$m^3/plot$		Measured or estimated from literature	Only once at project start and where mandatory
V_{tr}	Commercial volume of tree tr	m^3		Measured or estimated from literature	Only once at project start and where mandatory
w	1, 2, 3, ..., W wood product class (sawn-wood, wood-based panels, other industrial roundwood, paper and paper board and other)	dimensionless		Defined	Only once at project start and where mandatory
W_{cl}	N_{cl}/N				
WW_w	Wood waste for wood product class w – the fraction immediately emitted through mill inefficiency	dimensionless		Measured or estimated from literature	Only once at project start
XF	Plot expansion factor from per plot values to per hectare values	dimensionless		Calculated	Only once at project start and where mandatory
z	1, 2, 3, ..., Z post deforestation zones with a characteristic mixture of final post-deforestation classes (fc)				

9.2 Description of the Monitoring Plan

There are three main monitoring tasks:

- 1) Monitoring actual carbon stock changes and GHG emissions in the project area (Section 8.2.20);
- 2) Monitoring leakage (Section 8.3); and
- 3) Ex post calculation of net GHG emission reductions (Section 8.4).

Prepare a monitoring plan describing how these tasks will be implemented. The monitoring plan must include the following sections for each task:

- a) Technical description of the monitoring tasks;
- b) Data to be collected (see Section 9.1);
- c) Overview of data collection procedures;
- d) Quality control and quality assurance procedures;
- e) Data archiving; and
- f) Organization and responsibilities of the parties involved in all of the above.

To allow transparent comparison between ex ante and ex post estimates, use the same formats and tables presented in Steps 1–9 of this methodology to report the results of monitoring.

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<https://doi.org/10.1093/forestscience/44.2.272>

APPENDIX 1: NOTATIONS AND CHARTS

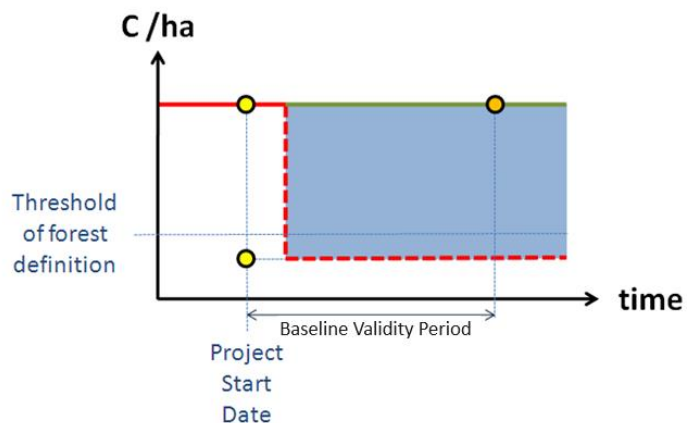
A1.1 Notations

Notations

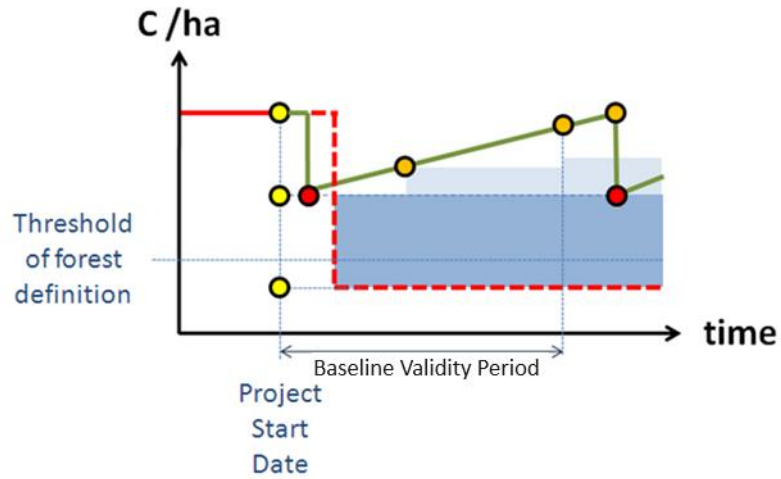
- Historical carbon stocks
- - - Projected carbon stocks (Baseline)
- Project scenario carbon stocks
- Emission reductions always claimed
- Emission reductions conservatively not claimed
- Mandatory *ex ante* measurements
- Optional *ex post* measurements
- Mandatory *ex post* measurements

A1.2 Activity-specific Charts

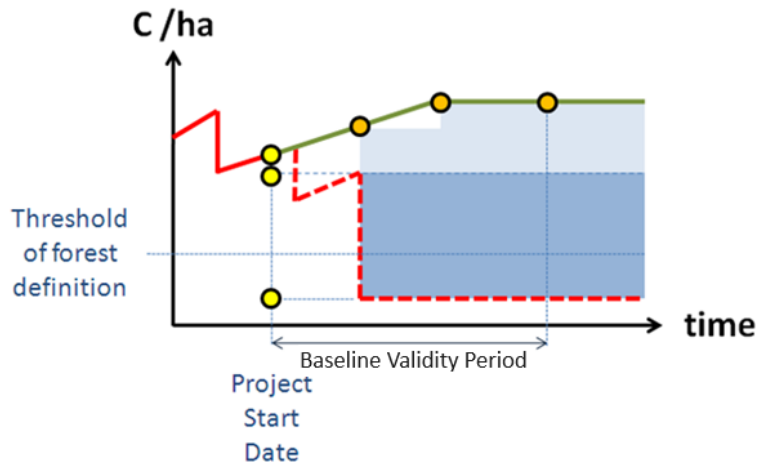
A - Avoided Deforestation without Logging



B – Avoided Deforestation with Logging in the Project Case

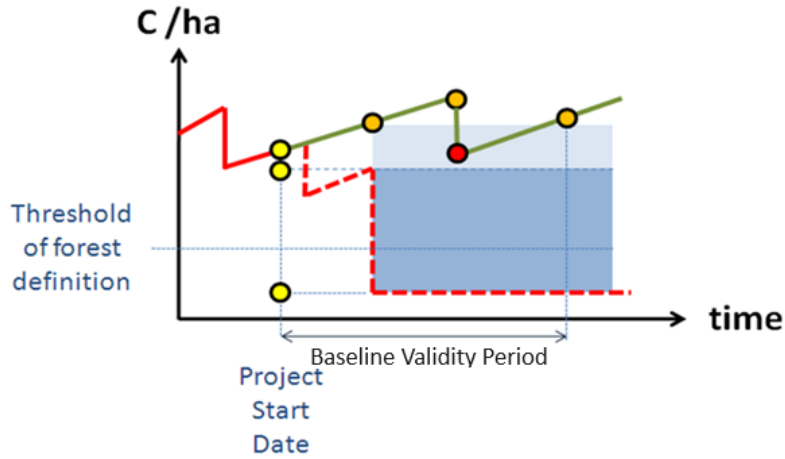


C – Avoided Deforestation with Logging Suppression



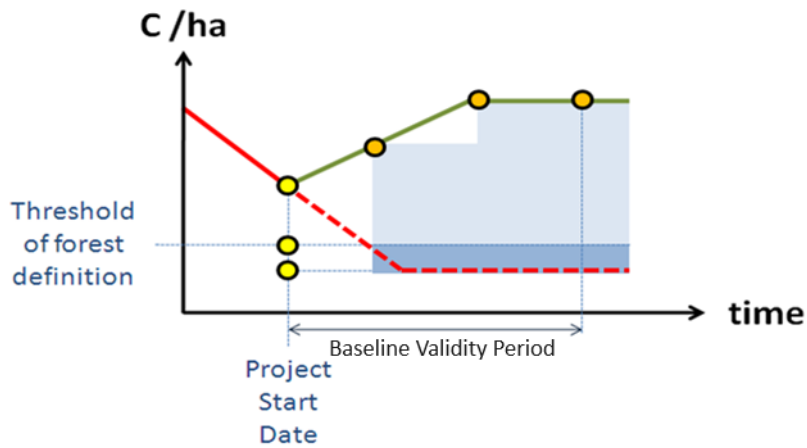
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

D – Avoided Deforestation with Logging in the Baseline and Project Cases



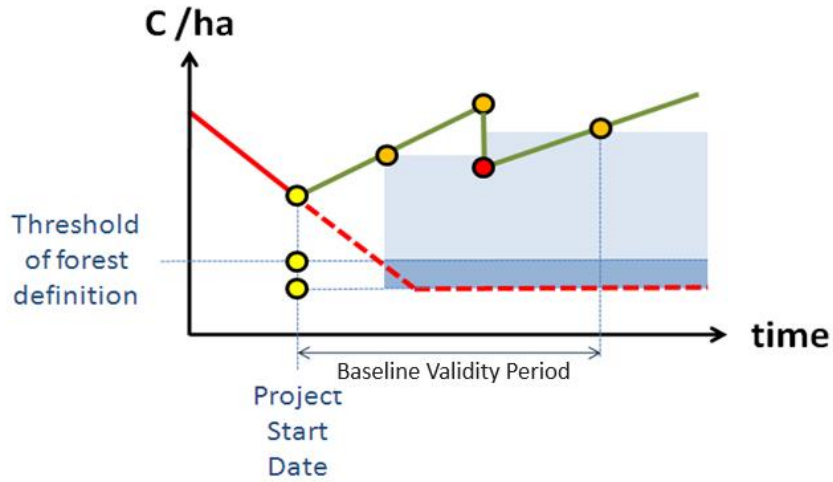
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

E - Avoided Deforestation of Degrading Forest



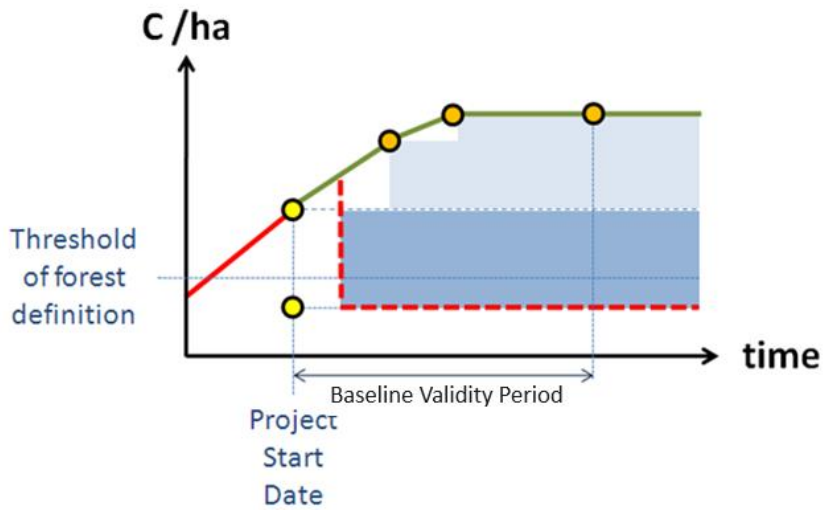
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

F - Avoided Deforestation of Degrading Forest with Logging in the Project Case

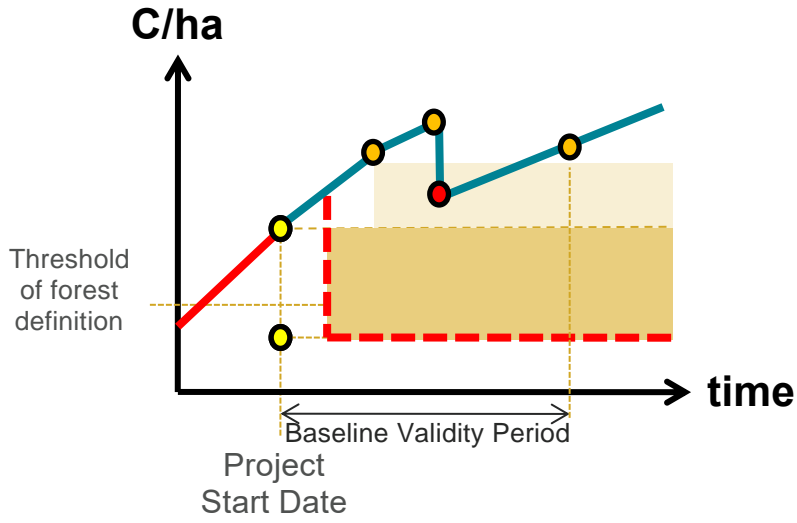


Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

G – Avoided Deforestation of Secondary Forest



H – Avoided Deforestation of Secondary Forest with Logging in the Project Case



APPENDIX 2: TESTING SIGNIFICANCE OF GHG EMISSIONS

The following stepwise procedure must be used to test the significance of GHG emissions. It is an adaptation of the CDM *Tool for testing the significance of GHG emissions in A/R CDM project activities, v01*. The procedure may be used to justify the omission of pools and GHG sources within the project boundaries, as well as to justify the omission of GHG emissions resulting from leakage mitigation measures.

The significance of GHG emissions by source and carbon stock changes by pool must be at minimum tested ex ante to justify the project boundaries and at baseline reassessment. The significance of leakage GHG emissions must be tested ex ante for the entire baseline validity period and ex post for a specific monitoring period.

- 1) Define the period over which the significance will be tested (i.e., either a baseline validity period for ex ante estimates or a specific monitoring period or annually for ex post estimates).
- 2) Identify and estimate the following where relevant:
 - a) GHG emissions by source (per each source) to be included and tested for the specified period. Estimation must be based on site/project-specific data, scientific peer-reviewed literature and/or the most recent default emission factors provided by IPCC.
 - b) GHG emissions attributable to net carbon stock changes by pool (per each pool to be included and tested). The estimation of net carbon stock changes must follow the methodology and be consistent with the baseline scenario and project activities. Estimation must be based on site/project-specific data, scientific peer-reviewed literature and/or the most recent default emission factors provided by IPCC.
 - c) Leakage GHG emissions by source attributable to project leakage mitigation measures (i.e., net carbon stock changes in above- and belowground tree biomass, emissions associated with biomass burning and nitrogen application) that the planned leakage mitigation measures are expected to cause during the baseline validity period. Estimation must follow sound procedures consistent with calculation approaches in the applicable activity-type module(s). Estimation must be based on site/project-specific data, scientific peer-reviewed literature and/or the most recent default emission factors provided by IPCC.
- 3) Where needed, convert the GHG emissions to CO₂e using 100-year global warming potential (GWP) values from the latest version of the *VCS Standard*.
- 4) Calculate the relative contributions of the GHG emissions listed in Steps 2a–c above according to the following equation:

$$RC_{E_i} = \frac{E_i}{\sum_{i=1}^I E_i} \quad (A2)$$

Where:

- RC_{E_i} = Relative contribution of each source i to the sum of project and leakage GHG emissions
- E_i = GHG project and leakage emissions for source i as estimated under Steps 2a-c above
- i = Index for individual sources of project and leakage GHG emissions due to leakage mitigation measures (I = total number of sources considered in Step 2)

- 5) Rank the GHG emissions in descending order of their relative contributions RC_{E_i} and order them according to their ranks (i.e., the lowest emission must get the highest rank and must occupy the last position in the ordered sequence of leakage emissions).
- 6) Start calculating the cumulative sum of the relative contributions RC_{E_i} (ordered according to Step 5), beginning with the lowest rank. Cease the summation when the cumulative sum reaches the lowest value not less than the threshold of 0.95.

The GHG and project leakage emissions by source excluded from the cumulative sum in Step 6 are considered insignificant where their total is lower than five percent of net anthropogenic GHG ERRs in the project area. Otherwise, the procedure described in Step 6 must be continued beyond the threshold of 0.95 until this condition is met. Even where they are insignificant, project proponents may include any qualifying sources and sinks in the project case.

For the purposes of testing GHG emissions significance, the net GHG ERRs must be calculated before discounting the cumulative GHG emissions resulting from leakage.

Significance test calculations must be summarized in the PD or monitoring reports and detailed in a calculation spreadsheet to be shared with the VVB and Verra.

APPENDIX 3: METHODS TO ESTIMATE CARBON STOCKS

A3.1 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 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.

A3.2 Temporary or Permanent Plots

Plots may 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 monitoring plot locations. Where local markers are used, these should not be visible. Where trees markers are required (e.g., if plots are also used for ecological or structural monitoring), these should be as inconspicuous 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 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.

A3.3 Definition of Sample Size and Allocation Among LU/LC Classes

The number of sample plots is estimated as dependent on accuracy, the 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 may initially be estimated by using a desired level of accuracy (10 percent of sampling error at 90 percent confidence level), and

by allocating the estimated sample size proportionally to the area of each class,⁴³ using Eqs. (A3-1) and (A3.2) respectively. Then, once data on carbon stock variability within each class become available, the sample size and allocation is recalculated using the methodology described by Wenger (1984),⁴⁴ which also accounts for the cost of sampling (see Eqs. A3-3 and A3-4).

Eq. A3-1 was chosen because it works with percentages rather than absolute units (biomass, carbon or CO₂), and coefficient of variation data may be more easy to find in the literature at the beginning of a project activity. The initial allocation of sample plots must be proportional to the area of LU/LC classes, but with a minimum of 5 plots per class. The t student value for a 95 percent confidence level is approximately equal to 2 when the number of sample plots is greater than 30. As the first step, use 2 as the t student value, and where the resulting n is less than 30, use the new n to get a new t student value and conduct a new estimation of the sample size. This process may be repeated until the calculated n is stabilized.

$$n = \frac{t_{st}^2 \times (CV\%)^2}{(E\%)^2 + \frac{t_{st}^2 \times (CV\%)^2}{N}} \quad (A3-1)$$

$$n_{cl} = n \times \frac{N_{cl}}{N} \quad (A3-2)$$

Where:

- cl = 1, 2, 3, ..., Cl LU/LC classes
- Cl = Total number of LU/LC classes
- t_{st} = t student value for a 90 percent 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 ($\pm 10\%$)
- $CV\%$ = 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 in proportion to class size; where 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), where $N = \sum_{cl=1}^{Cl} N_{cl}$

In Eq. (A3-3) the standard deviation of each LU/LC class (S_{cl}) must be determined using the actual data from the most recent field measurement. The allowable error is an absolute value, and may be estimated as ± 10 percent of the observed overall average carbon stock per hectare. It is possible to reasonably modify the LU/LC class limits and the sample size after each monitoring event based on the actual variation in carbon stock changes determined from taking n sample plots. Where costs for

⁴³ Loetsch, F., & Haller, K. (1964). *Forest Inventory*. Volume 1. BLV-Verlags Gesellschaft.

⁴⁴ Wenger, K.F. (ed). (1984). *Forestry Handbook* (2nd edition). John Wiley and Sons.

selecting and measuring plots are not a significant consideration, the calculation and allocation of sample size may be simplified by setting C_{cl} equal to 1 across all LU/LC classes.

$$n = \left(\frac{t_{st}}{E}\right)^2 \left[\sum_{cl=1}^{Cl} W_{cl} \times S_{cl} \times \sqrt{C_{cl}}\right] \times \left[\sum_{cl=1}^{Cl} W_{cl} \times S_{cl} / \sqrt{C_{cl}}\right] \quad (\text{A3-3})$$

$$n_{cl} = n \times \frac{W_{cl} \times S_{cl} / \sqrt{C_{cl}}}{\sum_{cl=1}^{Cl} W_{cl} \times S_{cl} / \sqrt{C_{cl}}} \quad (\text{A3-4})$$

Where:

- cl = 1, 2, 3, ... Cl LU/LC classes
- Cl = Total number of LU/LC classes
- t_{st} = t student value for a 95 percent confidence level, with $n - 2$ degrees of freedom
- E = Allowable error (± 10 percent 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 allocated in proportion to $W_{cl} \times S_{cl} / \sqrt{C_{cl}}$. Where $n_{cl} < 3$, 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 LU/LC class cl

A3.4 Sample Plot Size

The plot area a has major influence on sampling intensity, time and resources spent on 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),⁴⁵ the relationship between the coefficient of variation and plot area may be denoted as follows:

$$CV_2^2 = CV_1^2 \sqrt{(a_1/a_2)} \quad (\text{A3-5})$$

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 is reduced, permitting the use of small sample sizes at the same precision level. Usually, the size of plots is between 100 m² for dense stands and 1000 m² for open stands.⁴⁶

⁴⁵ Freese, F. (1962). *Elementary Forest Sampling*. USDA Handbook 232. GPO.

⁴⁶ It is recommended to use sample plots of equal area for the strata. This methodology is not applicable where sample plot areas vary within a stratum. The density of trees to be considered is that at tree maturity.

A3.5 Plot Location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more “convenient” positions), permanent sample plots must 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 may 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 plots must be recorded and archived.

Sampling plots should be as evenly distributed as possible. For example, where one stratum consists of three geographically separated sites, it is proposed to:

- 1) Divide the total stratum area by the number of plots, resulting in the average area represented by each plot.
- 2) 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 from sampling plot locations, 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 field sampling and thus a perfectly even distribution of sampling plots is not possible. This is also the case where pre-existing inventory data are used. Uneven distribution of sampling plots will be accepted provided that statistical representativeness and the use of standard sampling techniques are applied, clearly reported and archived.

A3.6 Estimation of Carbon Stocks

The total average carbon stock per hectare (carbon density) in an LU/LC class is estimated by the following equation.

$$C_{tot_{cl}} = Cab_{cl} + Cbb_{cl} + Cdw_{cl} + Cl_{cl} + Csoc_{cl} - Cwp_{cl} \quad (A3-6)$$

Where:

- $C_{tot_{cl}}$ = Average carbon stock per hectare in all accounted carbon pools of the LU/LC class cl (t CO_{2e}/ha)
- Cab_{cl} = Average carbon stock per hectare in aboveground biomass carbon pool of LU/LC class cl (t CO_{2e}/ha)
- Cbb_{cl} = Average carbon stock per hectare in belowground biomass carbon pool of LU/LC class cl (t CO_{2e}/ha)

- Cdw_{cl} = Average carbon stock per hectare in dead wood carbon pool of LU/LC class cl (t CO₂e/ha)
 Cl_{cl} = Average carbon stock per hectare in litter carbon pool of LU/LC class cl (t CO₂e/ha)
 $Csoc_{cl}$ = Average carbon stock per hectare in soil organic carbon pool of LU/LC class cl (t CO₂e/ha)
 Cwp_{cl} = Average carbon stock per hectare in wood products carbon pool of LU/LC class cl

Note – Cwp_{cl} is subtracted where cl is an initial pre-deforestation forest class in the baseline case. It is added where cl is a final post-deforestation class or a forest class not deforested in the project scenario.

A3.7 Estimation of Carbon Stocks in Living Biomass Carbon Pools (Cab_{cl} and Cbb_{cl})

In a forest, most of the carbon is stored in the tree component of living biomass. Hence, for the majority of forest classes it is sufficient to estimate carbon stock in the tree component and to ignore carbon stock in the non-tree vegetation component.

However, there may 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.⁴⁷

The living biomass components that are measured and the minimum diameter at breast height (DBH) above which trees are measured must be specified in the PD.

Carbon stocks in living biomass are given by the following equations:

$$Cab_{cl} = Cabt_{cl} + Cabnt_{cl} \quad (A3-7)$$

$$Cbb_{cl} = Cbbt_{cl} + Cbbnt_{cl} \quad (A3-8)$$

Where:

- Cab_{cl} = Average carbon stock per hectare in aboveground biomass carbon pool of LU/LC class cl (t CO₂e/ha)
 $Cabt_{cl}$ = Average carbon stock per hectare in aboveground tree biomass carbon pool of LU/LC class cl (t CO₂e/ha)
 $Cabnt_{cl}$ = Average carbon stock per hectare in aboveground non-tree biomass carbon pool of LU/LC class cl (t CO₂e/ha)
 Cbb_{cl} = Average carbon stock per hectare in belowground biomass carbon pool of LU/LC class cl (t CO₂e/ha)
 $Cbbt_{cl}$ = Average carbon stock per hectare in belowground tree biomass carbon pool of LU/LC class cl (t CO₂e/ha)
 $Cbbnt_{cl}$ = Average carbon stock per hectare in belowground non-tree biomass carbon

⁴⁷ The same carbon pools are to be estimated for the two classes of an LU/LC-change category.

pool of LU/LC class c_l (t CO₂e/ha)

A3.8 Tree Component ($C_{abt_{cl}}$ and $C_{bb_{cl}}$)

The carbon stock of trees may be estimated using: existing forest inventory data or direct field measurements.

A3.8.1 Estimations using Forest Inventory Data

(See the most recent version of the GOF-C-GOLD sourcebook for REDD for more detail.)

Forest inventory data typically come in two different forms: stand tables and stock tables.

A3.8.1.1 Stand Tables

Stand tables 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 (see Section A3.8.2.1).

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 or heavily logged forests. To overcome this problem Gillespie et al. (1992) developed a technique that is 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 (cm)	Midpoint Diameter (cm)	Number of Stems Per ha (no.)
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

A3.8.1.2 Stock Tables

Stock tables indicate the volume of merchantable timber by diameter class or total per hectare. Where volume data are only available for commercial species, do not use them for estimating carbon stocks because a large and unknown proportion of the total volume is excluded.

The biomass density may 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 Table 66.

Table 66: Values of BCEF for Application to Volume Data

(Modified by GOF-C-GOLD (2008) from Table 4.5 in IPCC GL AFOLU)

Forest Type	Growing Stock Volume Average and Range (<i>VOB</i> , 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	1.8–3.04	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 exactly match the definition given above, GOF-C-GOLD (2008) recommend the following:

- 1) Where the definition of *VOB* also includes stem tops and large branches, the lower bound of the range for a given growing stock should be used.
- 2) Where the definition of *VOB* has a large minimum top diameter or the *VOB* is comprised of trees with particularly high basic wood density, 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*, GOF-C-GOLD (2008) proposes volume expansion factors (*VEF*). However, due to large uncertainties in the volume of smaller *DBH* classes, inventories with a minimum diameter 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:

- a) For $VOB30 < 250 \text{ m}^3/\text{ha}$ use the following equation:
$$VEF = \exp(1.300 - 0.209 \times \ln(VOB30)) \quad (\text{A3-9})$$
- b) For $VOB30 > 250 \text{ m}^3/\text{ha}$ 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 $VOB30 = 100 \text{ m}^3/\text{ha}$

- 1) **Calculate the *VEF*:** $VEF = \exp(1.300 - 0.209 \times \ln(100)) = 1.40$
- 2) **Calculate *VOB10*:** $VOB10 = 100 \text{ m}^3/\text{ha} \times 1.40 = 140 \text{ m}^3/\text{ha}$
- 3) **Take *BCEF* from Table 67:** *BCEF* for tropical hardwood with growing stock of $140 \text{ m}^3/\text{ha} = 1.3$
- 4) **Calculate above-ground biomass density:** $= 1.3 \times 140 = 182 \text{ t}/\text{ha}$

Below-ground tree biomass (roots) is almost never measured, but instead is included through a relationship to aboveground biomass (usually a root-to-shoot ratio). Where the vegetation strata correspond with tropical or subtropical types listed in Table 67 (modified by GOF-C-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 67: Roots to Shoot Ratios

 (Modified⁴⁸ by GOCF-GOLD, 2008 from Table 4.4 in IPCC GL AFOLU)

Domain	Ecological Zone	Aboveground Biomass	Root-to-shoot Ratio	Range
Tropical	Tropical rainforest	<125 t/ha	0.20	0.09–0.25
		>125 t/ha	0.24	0.22–0.33
	Tropical dry forest	<20 t/ha	0.56	0.28–0.68
		>20 t/ha	0.28	0.27–0.28
Subtropical	Subtropical humid forest	<125 t/ha	0.20	0.09–0.25
		>125 t/ha	0.24	0.22–0.33
	Subtropical dry forest	<20 t/ha	0.56	0.28–0.68
		>20 t/ha	0.28	0.27–0.28

A3.8.2 Estimations Using Direct Field Measurements

Two methods are available to estimate the carbon stock of trees: allometric equations and biomass expansion factors (*BEF*). The allometric equations method is preferred. However, where no biomass equations are available for a given species or forest type, the *BEF* method must be used.

A3.8.2.1 Allometric 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 where relevant (depending on the form of the allometric equation) the height of all trees above a minimum *DBH*.
- 2) Choose or establish the appropriate allometric equations for each species or species group *j*.

$$TBab_j = f_j(DBH, H)_{ab} \quad (A3-10)$$

Where:

$TBab_j$ = Aboveground biomass of a tree of species, species group or forest type *j* (kg/tree)

⁴⁸ The modification corrects an error in the table based on communications with Karel Mulrone, the lead author of the peer reviewed paper from which the data were extracted.

Note – the unit (kg/tree) may instead be t/tree or t/ha, depending on the type of allometric equation

$f_j(DBH,H)_{ab}$ = Allometric equation for species, group of species or forest type j , linking aboveground tree biomass (in kg/tree – see the note above) to diameter at breast height (DBH) and possibly tree height (H)

The allometric equations are preferably locally derived and forest type-specific. Where allometric equations developed from a biome-wide database are used,⁴⁹ a few trees of different species and sizes within the project area (or forest class), but outside the sample plots, must be destructively harvested and their biomass estimated for comparison against the selected equation. The number of trees to be felled depends on the number of species and the range of size of trees that 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. Where the biomass estimated from the harvested trees is within about ± 10 percent of that predicted by the equation, then the selected equation may be deemed suitable for the project. Otherwise, full allometric models valid for the project must be developed. In this case, the sample must be increased until obtaining an appropriated statistical fit (all model variables should be statistically significant and the R^2 of the equation should be at least 0.7). Where resources permit, carbon content may be determined in the laboratory. Finally, allometric equations are constructed relating the biomass to values from easily measured variables, such as basal area or tree diameter and total height (see Chapter 4.3 in GPG LULUCF). Generic allometric equations may be used where it is demonstrated that they are conservative.

- 3) Estimate the carbon stock in aboveground 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.

$$TCab_{tr} = T Bab_{tr} \times CF_j \quad (A3-11)$$

Where:

$TCab_{tr}$ = Carbon stock in aboveground biomass of tree tr (kg C/tree) or (t C/tree)
 $T Bab_{tr}$ = Aboveground biomass of tree tr (kg/tree) or (t/tree)
 CF_j = Carbon fraction for tree tr of species, group of species or forest type j (t C/t d.m.)

- 4) Calculate the carbon stock in aboveground biomass per plot on a per area basis. Calculate by summing the carbon stock in aboveground biomass of all trees within each plot and multiplying by a plot expansion factor that is proportional to the measurement plot area. Where carbon stock is calculated in kilograms, divide by 1000 to convert to tonnes.

⁴⁹ Such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF

$$PCab_{pl} = \frac{\sum_{tr=1}^{TR_{pl}} TCab_{tr} \times XF}{1000} \quad (A3-12)$$

$$XF = 10000/AP \quad (A3-13)$$

Where:

- $PCab_{pl}$ = Carbon stock in aboveground biomass in plot pl (t C/ha)
 $TCab_{tr}$ = Aboveground biomass of tree tr (kg/tree) or (t/tree)
 XF = Plot expansion factor from per plot values to per hectare values (dimensionless)
 AP = Plot area (m²)
 tr = 1, 2, 3, ..., TR_{pl} number of trees in plot pl (dimensionless)

- 5) Calculate average carbon stock by averaging across all plots within an LU/LC class.

$$Cab_{cl} = \frac{44}{12} \times \frac{\sum_{pl=1}^{PL_{cl}} PCab_{pl}}{PL_{cl}} \quad (A3-14)$$

Where:

- Cab_{cl} = Average carbon stock per hectare in aboveground biomass in LU/LC class cl (t CO₂e/ha)
 $PCab_{pl}$ = Carbon stock in aboveground biomass in plot pl (t C/ha)
 $44/12$ = Ratio converting C to CO₂e
 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 carbon stock in belowground biomass of tree tr using root-shoot ratios and aboveground carbon stock and apply Steps 4 and 5 to belowground biomass.

$$TCbb_{tr} = TCab_{tr} \times R_j \quad (A3-15)$$

$$PCbb_{pl} = \frac{\sum_{tr=1}^{TR_{pl}} TCbb_{tr} \times XF}{1000} \quad (A3-16)$$

$$Cbb_{cl} = \frac{44}{12} \times \frac{\sum_{pl=1}^{PL_{cl}} PCbb_{pl}}{PL_{cl}} \quad (A3-17)$$

Where:

- $TCbb_{tr}$ = Carbon stock in belowground biomass of tree tr (kg C/tree) or (t C/tree)
 $TCab_{tr}$ = Carbon stock in aboveground biomass of tree tr (kg C/tree) or (t C/tree)
 R_j = Root-shoot ratio appropriate for species, group of species or forest type j (dimensionless)
 $PCbb_{pl}$ = Carbon stock in belowground biomass in plot pl (t C/ha)
 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 belowground biomass in LU/LC class cl (t CO₂e/ha)
 $44/12$ = Ratio converting C to CO₂e
 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)

A3.8.2.2 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 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 of each tree based on locally derived equations by species, species group or forest type. Then, sum for all trees within a plot, and express as commercial volume per unit of area (m^3/ha). These steps may be combined where there are available field instruments that measure volume per hectare directly (e.g., a Bitterlich relascope). Volume per plot is an ancillary variable and may be needed in some cases to estimate the proper biomass expansion factor or the root-shoot ratio.⁵⁰

$$V_{tr} = f_j(DBH, H)_v \quad (A3-18)$$

$$V_{pl} = \sum_{tr=1}^{TR} V_{tr} \times XF \quad (A3-19)$$

$$XF = \frac{10\,000}{AP} \quad (A3-20)$$

Where:

V_{tr}	=	Commercial volume of tree tr ($m^3/tree$)
V_{pl}	=	Commercial volume of plot pl ($m^3/plot$)
$f_j(DBH, H)_v$	=	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) above to choose them.

These parameters may 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.

Where a significant amount of effort is required to develop local BEFs and root-shoot ratios, involving, for instance, harvest of trees, this method is not recommended. Instead, the

⁵⁰ See for example Brown, S. (1997). *Estimating Biomass and Biomass Change of Tropical Forests: A Primer*. FAO Forestry Paper 134, UN FAO.

resources should be used to develop local allometric equations as described in the allometric method above (refers to Chapter 4.3 in GPG LULUCF). Where this is not possible either, national species-specific defaults for *BEF* and *R* may be used. Since both *BEF* and the root-shoot ratio (*R*) are age or stand density-dependent, use of age-dependent or stand density-dependent equations (for example, volume per hectare) is preferred. Stem wood volume may be very small in young stands and *BEF* may be very large, while for old stands *BEF* is usually significantly smaller. Therefore using average *BEF* values 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 *BEF* may result in significant error).

- 4) Convert the volume of the commercial component of each tree in a plot into carbon stock in aboveground biomass and belowground biomass per tree via basic wood density, *BEF*, root-shoot ratio and carbon fraction (applicable to the species):

$$TCab_{tr} = V_{tr} \times D_j \times BEF_{pl} \times CF_j \quad (A3-21)$$

$$TCbb_{tr} = TCab_{tr} \times R_{j,pl,tr} \quad (A3-22)$$

Where:

$TCab_{tr}$	=	Carbon stock in aboveground biomass of tree <i>tr</i> (kg C/tree)
$TCbb_{tr}$	=	Carbon stock in belowground biomass of tree <i>tr</i> (kg C/tree)
V_{tr}	=	Commercial volume of tree <i>tr</i> (m ³ /tree)
D_j	=	Wood density for species <i>j</i> ; see IPCC GPG-LULUCF, 2003 Table 3A.1.9 or USDA wood density table ⁵¹ (t d.m./m ³)
BEF_{pl}	=	Biomass expansion factor for converting volumes of extracted round wood to total aboveground biomass (including bark), applicable to tree <i>tr</i> in plot <i>p</i> (dimensionless)
CF_j	=	Carbon fraction applicable to tree <i>tr</i> of species <i>j</i> (t C/t d.m.)
$R_{j,pl,tr}$	=	Root-shoot ratio, applicable to tree <i>tr</i> of species <i>j</i> in plot <i>p</i> (dimensionless)

- 5) Continue with Section A3.8.A3.8.2.1 Step (4) of the allometric equation method to calculate the carbon stock in aboveground and belowground biomass by aggregating successively at the tree, plot and LU/LC class levels.

A3.9 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

⁵¹ Reyes et al., (1992). *Wood Densities of Tropical Tree Species*. USDA.

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 non-tree vegetation components are usually based on destructive harvesting, drying and weighing. 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 1 m² 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 m², depending on the size, distribution and frequency of this vegetation).

Allometric equations may be developed for specific forest species (e.g., bamboo) or crop types (e.g., coffee). When using destructive sampling, apply the following steps:

- 1) Place the clip frame at the sampling site. Where necessary, open the frame and place around the vegetation.
- 2) Clip all vegetation within the frame to ground level. Cut everything growing within the quadrat (ground surface not three-dimensional column) and sample this.
- 3) Weigh the sample and remove a well-mixed sub-sample for determination of dry-to-wet mass ratio. Weigh the sub-sample in the field, then oven-dry to constant mass (usually at ~70 °C).
- 4) Calculate the dry mass of each sample. Where a sub-sample was taken for determination of moisture content use the following equation:

$$\text{Dry mass} = \left(\frac{\text{subsample dry mass}}{\text{subsample fresh mass}} \right) \times \text{fresh mass of whole sample} \quad (\text{A3-23})$$

- 5) The carbon stock in aboveground 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 CO₂/C ratio. To calculate the average carbon stock per LU/LC class, average over all samples as follows:

$$Cabnt_{cl} = \frac{\sum_{pl=1}^{PL_{cl}} DM_{pl} \times XF \times CF_{pl} \times 44/12}{PL_{cl}} \quad (\text{A3-24})$$

Where:

$Cabnt_{cl}$	=	Average carbon stock per hectare in aboveground non-tree biomass carbon pool of LU/LC class cl (t CO ₂ e/ha)
DM_{pl}	=	Dry mass of sample pl (t d.m.)
XF	=	Plot expansion factor = [10.000 / Plot Area (m ²)] (dimensionless)
CF_{pl}	=	Carbon fraction of sample pl (t C/t d.m.)
$44/12$	=	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)

- 6) The carbon stock per hectare of belowground non-tree biomass is calculated by multiplying the estimated aboveground estimate by an appropriate root to shoot ratio.

A3.10 Estimation of Carbon Stocks in Dead Wood Carbon Pool ($C_{dw_{cl}}$)

Carbon stocks in the dead wood carbon pool may be significant in forest classes although are usually insignificant or zero in most agricultural and pastoral LU/LC classes. However, where burning is used to clear slash, dead wood may be a significant component of carbon stocks in agricultural/pasture lands, especially in the short term. Therefore, in most cases it is conservative to ignore the dead wood carbon pool.

Dead wood 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.

$$C_{dw_{cl}} = C_{sdw_{cl}} + C_{ldw_{cl}} \quad (\text{A3-25})$$

Where:

$C_{dw_{cl}}$ = Average carbon stock per hectare in dead wood carbon pool of LU/LC class cl (t CO₂e/ha)

$C_{sdw_{cl}}$ = Average carbon stock per hectare in standing dead wood carbon pool of LU/LC class cl (t CO₂e/ha)

$C_{ldw_{cl}}$ = Average carbon stock per hectare in lying dead wood carbon pool of LU/LC class cl (t CO₂e/ha)

Standing dead wood must be measured using the sampling criteria and monitoring frequency used for measuring live trees. Lying dead wood must be measured using the transect method as explained below. The description of the method to measure lying dead wood is taken from Harmon and Sexton (1996).

A3.10.1 Standing Dead Wood ($C_{sdw_{cl}}$)

- 1) Within the plots delineated for live trees, the diameter at breast height (*DBH*) of standing dead trees may also be measured. The standing dead wood is categorized under the following four decomposition classes:
 - a) Tree with branches and twigs that resemble a live tree (except for leaves);
 - b) Tree with no twigs, but with persistent small and large branches;
 - c) Tree with large branches only;
 - d) Bole (trunk) only, no branches.
- 2) 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 may be measured using a clinometer.
- 3) Top diameter may 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 equal to:

$$\text{True diameter}(m) = \frac{\text{Distance eye to tree}(m)}{\text{Distance eye to ruler}(m)} \times \text{Ruler measurement}(m) \quad (\text{A3-26})$$

Distance may also be measured with a laser range finder.

- 4) 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 percent of aboveground biomass for hardwood/broadleaf species and 5–6 percent for softwood/conifer species).
- 5) 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, and estimated as the volume of a truncated cone:

$$Volume(m^3) = 1/3 \times \pi \times H \times (r_1^2 + r_2^2 + r_1 \times r_2) \quad (A3-27)$$

Where:

- H* = Height of tree (m)
*r*₁ = Radius at base of tree (m)
*r*₂ = Radius at top of tree (m)

The volume is converted to dry biomass using the appropriate wood density *D_j* and then to carbon dioxide equivalents using the carbon fraction *C_{uff}* and CO₂/C ratio (44/12), as in the *BEF* method, but ignoring the biomass expansion factor.

- 6) 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 (4) of the allometric equation method (Section A3.8.2.1).

A3.10.2 Lying Dead Wood (*C_{ldw_c}*)

Lying dead wood is most efficiently measured using the line-intersect method. Only coarse dead wood above a predefined minimum diameter (e.g., greater than 10 cm) is measured with this method – dead wood of smaller diameters may be measured with litter.

- 1) 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 to avoid biasing the dead wood pool by damaging during tree measurement. Alternatively, separate and independent sampling of lying dead wood may be used, in which case dead wood transects must be randomly located (to avoid subjective choice of plot locations), without sample replacement, using the same procedure used for live trees.⁵² Their location must be permanently marked and their coordinates reported.
- 2) Along the length of the lines, measure the diameter of each intersecting piece of coarse dead wood above a predefined minimum diameter (e.g., greater than 10 cm). Calipers work best for measuring the diameter. A piece of dead wood should only be measured where: (a) more than 50 percent of the log is aboveground and (b) the sampling line crosses through at least 50 percent of the diameter of the piece. Where the log is hollow at the intersection point, measure the diameter of the hollow: the hollow portion in the volume estimates should be excluded.

⁵² Using this alternate approach, transects may be located in places distant to live tree plots, increasing sampling costs. Even where lying dead wood stocks are very homogeneous in all strata, implying that fewer samples will be required, the cost of additional displacements and work is unlikely to compensate for the decrease in sample size.

- 3) Assign each piece of dead wood to one of the three following density classes:
 - a) Sound
 - b) Intermediate
 - c) Rotten
- 4) To determine which 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.
- 5) 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 may 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 complete disc or a piece of reasonable size from the selected piece of dead wood and bring to the laboratory for wood density determination.
- 6) Submerge wood samples in water until saturation is reached. Weigh saturated samples. Then, dry samples at 105 °C for 26 hours. Extract and weigh samples again, quickly withdrawing samples from oven immediately before weighing so that no moisture is absorbed by dried samples before weighing.
- 7) 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:

$$Dm = \frac{1}{\frac{ps-po}{po} + \frac{1}{1.53}} \quad (\text{A3-28})$$

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.

- 8) For each density class, the volume is calculated separately as follows:

$$Volume(m^3/ha) = \pi^2 \times \left(\frac{d_1^2 + d_2^2 + \dots + d_n^2}{8 \times L} \right) \quad (\text{A3-29})$$

Where:

d_1, d_2, \dots, d_n	=	Diameters of intersecting pieces of dead wood (cm)
L	=	Length of the line (m)

- 9) The per hectare carbon stock in the lying dead wood carbon pool of each LU/LC class is calculated as follows:

$$Cldw_{cl} = \frac{\sum_{pl=1}^{PL_{cl}} (\sum_{dc=1}^{DC} Volume_{dc} \times D_{dc} \times CF_{dc} \times 44/12)_{pl}}{PL_{cl}} \quad (A3-30)$$

Where:

$Cldw_{cl}$	=	Average carbon stock per hectare in lying dead wood carbon pool of LU/LC class cl (t CO ₂ e/ha)
$Volume_{dc}$	=	Volume of lying dead wood in density class dc (m ³)
D_{dc}	=	Dead wood density of class dc (t d.m./m ³)
CF_{dc}	=	Carbon fraction of density class dc (t C/t d.m.)
$44/12$	=	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)

A3.11 Estimation of Carbon Stocks in the Litter Carbon Pool (CL_{cl})

In some forest ecosystems, carbon stocks in the litter pool are a significant component of total carbon stock while in anthropogenic ecosystems, particularly agricultural or pastoral systems, litter is almost absent.

Litter is defined as all dead organic surface material on top of mineral soil that is not considered in the lying dead wood pool. Some of this material is recognizable (e.g., 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 lying 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.

Where litter is measured, it should be sampled at the same time of year at each monitoring event in order to eliminate seasonal effects. The sampling technique is similar to that used for non-tree vegetation: a square frame of 1.0 m² made from PVC pipe or another suitable material may be used. The following description of sampling and data analysis techniques is taken from the sourcebook for LULUCF projects (Pearson et al., 2005).

- 1) Place the sampling frame at the sample site.
- 2) 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 weighing bag. Weigh the sample on-site, then oven-dry to a constant weight.
- 3) 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 is calculated.
- 4) Calculate the dry mass of the sample. Where a sub-sample is taken for determination of the moisture content, use Eq. (A3-23) to estimate the dry mass of the whole sample.

- 5) 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 CO₂/C ratio. To calculate the average carbon stock per LU/LC class, average over all samples (see Equation A3-24).

A3.12 Estimation of Carbon Stocks in Soil Organic Carbon Pool (C_{soc-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: depth, bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material) and the concentration of organic carbon within the sample.

The sample depth should be constant; 30 cm is usually a sufficient sampling depth.

- 1) Steadily insert the soil probe to a 30 cm depth. Where 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 that a stone or root 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.
- 2) Carefully extract the probe and place the sample into a bag. Because the carbon concentration of organic materials is much higher than that of mineral soil, including even a small amount of surface material may result in a serious overestimation of soil carbon stocks.
- 3) To reduce variability, aggregate four samples from each collection point for carbon concentration analysis.
- 4) At each sampling point, take two additional aggregated cores to determine bulk density. When taking cores for measurements of bulk density, care should be taken to avoid any excess or loss of soil from the cores.
- 5) Soil samples may be sent to a professional laboratory for analysis. Commercial laboratories routinely analyze plant and soil samples using standard techniques. The selected laboratory should follow commonly accepted standard procedures with respect to sample preparation (e.g., mixing and sieving), drying temperatures and carbon analysis methods.

For bulk density determination, ensure the laboratory dries the samples in an oven at 105 °C for a minimum of 48 hours. Where the soil contains coarse, rocky fragments, these must be retained and weighed. 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 carbon analysis, but only air-dried. However, the carbon concentration must be expressed on an oven dry basis at 105 °C. The dry combustion method using a controlled temperature furnace (e.g., a LECO CHN-2000 or equivalent) is recommended for determining total soil carbon, but the Walkley-Black method is also commonly used.

- 1) Calculate the bulk density of the mineral soil core:

$$Bulk\ density(g/cm^3) = \frac{ovendry\ mass\ (g/cm^3)}{core\ volume(cm^3) - \frac{mass\ of\ coarse\ fragments\ (g)}{density\ of\ rock\ fragments(g/cm^3)}} \quad (A3-31)$$

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/cm³.

- 2) Using the carbon concentration data obtained from the laboratory, the amount of carbon per unit area is given by:

$$C_{soc_{cl}}(t/ha) = [soil\ bulk\ density(g/cm^3) \times soil\ depth(cm) \times C] \times 100 \quad (A3-32)$$

In the above equation, C must be expressed as a decimal fraction. For example, 2.2 percent carbon is expressed as 0.022 in the equation.

- 3) The carbon stock per hectare in the soil organic carbon pool is calculated by averaging the carbon stock estimates for each LU/LC class:

$$C_{soc_{cl}} = \frac{\sum_{pl=1}^{PL_{pl}} C_{soc_{pl}}}{PL_{pl}} \quad (A3-33)$$

Where:

$C_{soc_{cl}}$	=	Average carbon stock per hectare in soil organic carbon pool of LU/LC class cl (t CO ₂ e/ha)
$C_{soc_{pl}}$	=	Carbon stock per hectare in soil organic carbon pool estimated for plot pl (t CO ₂ e/ha)
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)

A3.13 Estimation of Carbon Stocks in the Harvested Wood Products Carbon Pool ($C_{wp_{cl}}$)

The wood products carbon pool must be included where there is timber harvest in the baseline scenario prior to or in the process of deforestation and where project activities may significantly reduce the pool. The wood products carbon pool may be included where baseline activities may significantly reduce the pool. In this case, $C_{wp_{cl}}$ must be subtracted in the calculation of $C_{tot_{cl}}$ in the baseline case and may be added in the calculation of $C_{tot_{cl}}$ in the project case.

Carbon stocks in the wood product pool are those stocks that become wood products at the time of deforestation. They are divided in three fractions, as follows:

- 1) Short-term wood products: wood products and waste that will decay within 3 years; all carbon must be assumed to be lost immediately;
- 2) Medium-term wood products: wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function must be applied; and
- 3) Long-term wood products: wood products that are considered permanent (i.e., carbon is stored for 100 years or more); it may be assumed that no carbon is released.

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} may be accounted at the years of planned timber harvest, in which case monitoring is mandatory.

The proportion of carbon stock stored in each fraction of the wood products carbon pool must be obtained from specific studies applicable to local conditions or from country-specific data about the volume of timber harvested per forest class. Where data on the proportion of carbon stocks in each fraction of the wood product carbon pool are unavailable, it is conservative to assume that 100 percent of the carbon is stored in the long-term fraction in the baseline case (in which case no carbon is released into the atmosphere in the baseline case), and that 100 percent of the carbon is stored in the short-term fraction in the project case (in which case all carbon is emitted immediately in the project case).

Where data on carbon stocks in each fraction of wood products are available and timber harvest plans specifying harvest intensity per forest class in terms of volume extracted per hectare are available for the project area, use Method 1 (Section A3.13.1). Where approved harvest plans are not available use Method 2 (Section A3.13.2).

A3.13.1 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:

$$CXB_{w,icl,t} = \frac{1}{ABSLPA_{icl,t}} \times \left(\sum_{t=1}^{t^*} \sum_{j=1}^J VEX_{w,j,icl,t} \times D_j \times CF_j \times \frac{44}{12} \right) \quad (A3-34)$$

Where:

$CXB_{w,icl,t}$	=	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)
icl	=	1, 2, 3, ..., icl initial 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)
t^*	=	Year in which the area $ABSLPA_{icl,t}$ is deforested in the baseline case (dimensionless)
j	=	1, 2, 3, ..., J tree species (dimensionless)
$ABSLPA_{icl,t}$	=	Area of forest class icl deforested at year t^* (ha)
$VEX_{w,j,icl,t}$	=	Volume of timber for product class w of species j extracted from within forest class icl 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 d.m.)
44/12	=	Ratio of molecular weight of CO ₂ to carbon (dimensionless)

Step 2: Calculate the carbon stock in the wood products carbon pool extracted from the biomass at time t (year of deforestation).

$$Cwp_{icl,t} = \sum_{w=1}^W CXB_{w,icl,t} \times (1 - STF_w) \quad (A3-35)$$

Where:

- $Cwp_{icl,t}$ = Carbon stock in wood products carbon pool in initial forest class icl at time t (t CO₂e/ha)
 icl = 1, 2, 3, ..., icl 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)
 $CXB_{w,icl,t}$ = Mean stock of extracted biomass carbon by class of wood product w from forest class icl at time t (t CO₂e/ha)
 STF_w = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)

Step 3: Calculate the biomass carbon extracted at time t that becomes medium-term wood products at the time of deforestation.

$$Cwp_{mt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} \times (1 - STF_w) \times (1 - LTF_w)) \quad (A3-36)$$

Where:

- $Cwp_{mt,icl,t}$ = Carbon stock in the medium-term wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
 $Cwp_{icl,t}$ = Carbon stock in wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
 STF_w = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)
 LTF_w = Fraction of wood products that are considered permanent (i.e., carbon is stored for 100 years or more); it may be assumed no carbon is released (dimensionless)

Step 4: Calculate the biomass carbon extracted at time t that becomes long-term wood products at the time of deforestation.

$$Cwp_{lt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} \times (1 - STF_w) \times (1 - MTF_w)) \quad (A3-37)$$

Where:

- $Cwp_{lt,icl,t}$ = Carbon stock in long-term wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
 $Cwp_{icl,t}$ = Carbon stock in wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
 STF_w = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)
 MTF_w = Fraction of wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function must be applied

A3.13.2 Method 2: Commercial Inventory Estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of deforestation:

$$CXB_{icl,t} = Cab_{icl,t} \times \frac{1}{BCEF} \times Pcom_{icl} \quad (A3-38)$$

Where:

$CXB_{icl,t}$	=	Mean stock of extracted biomass carbon from initial forest class icl at time t (t CO ₂ e/ha)
$Cab_{icl,t}$	=	Mean aboveground biomass carbon stock in initial forest class icl at time t (t CO ₂ e/ha)
$BCEF$	=	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass (dimensionless)
$Pcom_{icl}$	=	Commercial volume as a percentage of total aboveground volume in initial forest class icl (dimensionless)
t	=	1, 2, 3, ..., T years, a year of the project crediting period (dimensionless)
icl	=	1, 2, 3, ..., lcl 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. Gross percentages of volume extracted may be assigned to wood product classes on the basis of local expert knowledge of harvest activities and markets.

Step 3: Calculate the biomass carbon extracted at time t that becomes wood products at the time of deforestation.

$$Cwp_{icl,t} = \sum_{w=1}^W CXB_{w,icl,t} \times (1 - STF_w) \quad (A3-39)$$

Where:

$Cwp_{icl,t}$	=	Carbon stock in wood products pool in initial forest class icl at time t (t CO ₂ e/ha)
icl	=	1, 2, 3, ..., lcl 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)
$CXB_{w,icl,t}$	=	Mean stock of extracted biomass carbon by class of wood product w from initial forest class icl at time t (t CO ₂ e/ha)
STF_w	=	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)

Step 4: Calculate the biomass carbon extracted at time t that becomes medium-term wood products at the time of deforestation.

$$Cwp_{mt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} \times (1 - STF_w) \times (1 - LTF_w)) \quad (A3-40)$$

Where:

$Cwp_{mt,icl,t}$	=	Carbon stock in medium-term wood products carbon pool at time of deforestation t of initial forest class icl (t CO ₂ e/ha)
$Cwp_{icl,t}$	=	Carbon stock in wood products carbon pool at time of deforestation t of initial forest class icl (t CO ₂ e/ha)

- STF_w = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)
- LTF_w = Fraction of wood products that are considered permanent (i.e., carbon is stored for 100 years or more); it may be assumed no carbon is released (dimensionless)

Step 5: Calculate the biomass carbon extracted at time t that becomes long-term wood products at the time of deforestation.

$$Cwp_{lt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} \times (1 - STF_w) \times (1 - MTF_w)) \quad (A3-41)$$

Where:

- $Cwp_{lt,icl,t}$ = Carbon stock in the long-term wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
- $Cwp_{icl,t}$ = Carbon stock in wood products carbon pool at time of deforestation t of initial forest class icl (t CO₂e/ha)
- STF_w = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon must be assumed to be lost immediately (dimensionless)
- MTF_w = Fraction of wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function must be applied (dimensionless)

APPENDIX 4: METHODS TO ESTIMATE EMISSIONS FROM ENTERIC FERMENTATION AND MANURE MANAGEMENT

A4.1 Estimation of CH₄ Emissions from Enteric Fermentation ($ECH4_{ferm,t,t}$)

The amount of methane⁵³ 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 equations:⁵⁴

$$ECH4_{ferm,t} = EF_1 \times Population_t \times 0.001 \times GWP_{CH4} \quad (A4-1)$$

$$Population_t = P_{forage_t} / (DBI \times 365) \quad (A4-2)$$

Where:

$ECH4_{ferm,t}$	=	CH ₄ emissions from enteric fermentation at year t (t CO ₂ e)
EF_1	=	Enteric CH ₄ emission factor for livestock group (kg CH ₄ /head/yr)
$Population_t$	=	Equivalent number of forage-fed livestock at year t (heads)
P_{forage_t}	=	Production of forage at year t (kg d.m./yr)
DBI	=	Daily biomass intake (kg d.m./head/day)
GWP_{CH4}	=	Global warming potential for CH ₄ , equal to 21 for the first commitment period (dimensionless)
0.001	=	Conversion factor of kilograms into tonnes (dimensionless)
365	=	Number of days per year (dimensionless)
t	=	1, 2, 3, ..., T years of project crediting period

The production of forage may be estimated by collecting production rates from the literature that represent the shrub species, climate, soil conditions and other features of the areas in which forage will be produced, or by sampling surveys.

⁵³ 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 CH₄, although ruminants are the largest source since they are able to digest cellulose due to the presence of specific microorganisms in their digestive tracts. The amount of CH₄ 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.

⁵⁴ Refer to Equations 10.19 and 10.20 in IPCC 2006 GL AFOLU or Equations 4.12 and 4.13 in GPG 2000 for agriculture.

Country-specific emission factors for enteric CH₄ emissions are documented in peer reviewed literature or may be obtained from national GHG inventories. Default values are given in Tables 10.10 and 10.11 in the IPCC 2006 Guidelines for AFOLU. It is important to select emission factors 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 may be interpolated using data on 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 forage types to be produced and the livestock group (see also Table 72).

A4.2 Estimation of CH₄ Emissions from Manure Management ($ECH4man_t$)⁵⁵

The storage and treatment of manure under anaerobic conditions produces CH₄. 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 CH₄ emissions are the amount of manure produced and the portion of manure that decomposes anaerobically. 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 anaerobically and may produce a significant quantity of CH₄. The temperature and storage retention time greatly affect the amount of methane produced. Where manure is handled as a solid (e.g., in stacks or piles) or deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH₄ is produced.

CH₄ emissions from manure management for forage-fed livestock may be estimated using IPCC methods.⁵⁶

$$ECH4man_t = EF_2 \times Population_t \times 0.001 \times GWP_{CH4} \quad (A4-3)$$

Where:

$ECH4man_t$	=	CH ₄ emissions from manure management at year t (t CO ₂ e)
EF_2	=	Manure management CH ₄ emission factor for livestock group (kg CH ₄ /head/yr)
$Population_t$	=	Equivalent number of forage-fed livestock at year t (heads)
GWP_{CH4}	=	Global warming potential for CH ₄ equal to 21 for the first commitment period (dimensionless)
0.001	=	Conversion factor of kilograms into tonnes (dimensionless)

⁵⁵ Taken from AR-AM0006, v1

⁵⁶ Refer to Equation 10.22 in the AFOLU volume of the IPCC 2006 Guidelines or Equation 4.15 in GPG 2000 for agriculture.

t = 1, 2, 3, ..., T years of the project crediting period

The best estimate of emissions is usually obtained using country-specific emission factors that have been published in peer-reviewed literature or in the national GHG inventory. Emission factors should reflect the actual duration of storage and type of treatment of animal manure in the management system used. Where 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.

A4.3 Estimation of N₂O Emissions from Manure Management (EN_2Oman_t)⁵⁷

Nitrous oxide emissions from manure management vary significantly between the type of management system used, and may also result in indirect emissions due to other forms of nitrogen loss from the system. The N₂O emissions from manure management may be estimated using the method provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000.⁵⁸

$$EN_{2Oman_t} = E_{dir}N_{2Oman_t} + E_{ind}N_{2Oman_t} \quad (A4-4)$$

$$E_{dir}N_{2Oman_t} = Population_t \times Nex \times EF_3 \times 0.001 \times 44/28 \times GWP_{N_{2O}} \quad (A4-5)$$

$$E_{ind}N_{2Oman_t} = Population_t \times Nex \times Frac_{gas} \times EF_4 \times 0.001 \times 44/28 \times GWP_{N_{2O}} \quad (A4-6)$$

Where:

EN_{2Oman_t}	=	N ₂ O emissions from manure management at year t (t CO ₂ e)
$E_{dir}N_{2Oman_t}$	=	Direct N ₂ O emissions from manure management at year t (t CO ₂ e)
$E_{ind}N_{2Oman_t}$	=	Indirect N ₂ O emissions from manure management at year t (t CO 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/yr)
EF_3	=	Emission factor for N ₂ O emissions from manure management for livestock group (kg N ₂ O-N/(kg N)/head/yr)
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)/head/yr)

Note – use of the IPCC default factor for EF_4 of 0.01 is recommended.

$Frac_{gas}$ = Fraction of managed livestock manure nitrogen that volatilizes as NH₃ and NO_x

⁵⁷ Taken from AR-AM0006, v1

⁵⁸ 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.

GWP_{N_2O}	=	in the manure management phase (kg NH ₃ -N and NO _x -N emitted/kg N) Global warming potential for N ₂ O, equal to 310 for the first commitment period (dimensionless)
44/28	=	Conversion of N ₂ O-N emissions to N ₂ O emissions (dimensionless)
0.001	=	Conversion factor of kilograms into tonnes (dimensionless)

The best estimate of annual nitrogen excretion rates for each livestock group is usually obtained using country-specific rates from published peer reviewed literature or from the national GHG inventory.

Where it is not possible to collect nor derive country-specific data, or appropriate data are not available from another country with similar conditions, default nitrogen excretion rates may 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 Tables 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU and default values for volatilization of NH₃ 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: INDICATIVE TABLES

Table 68: Guidance on Carbon Pool Selection Depending on the Land Use/Land Cover Change Category Considered⁵⁹

Type of Land Use/Land Cover Transition	Living Biomass (trees)		Dead Organic Matter			Soil
	Aboveground	Belowground	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 69: Present Availability of Optical Mid-resolution (10–60m) Sensors (GOFC-GOLD, 2008)

Nation	Satellite and sensor	Resolution and coverage	Cost (archive ⁶⁰)	Feature
USA	Landsat-5 TM	30 m 180×180 km ²	USD 600/scene USD 0.02/km ²	Images every 16 days to any satellite-receiving station. Operating beyond expected lifetime.
USA	Landsat-7 ETM+	30 m 60×180 km ²	USD 600/scene USD 0.06/km ²	In April 2003, failure of the scan line corrector resulted in data gaps outside of the central portion of images, seriously compromising data quality.
USA/Japan	Terra ASTER	15 m	USD 60/scene	Data are acquired on request and not routinely collected for all areas.

⁵⁹ 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.

⁶⁰ Some acquisitions may be programmed (e.g., DMC, SPOT). The cost of programmed data is generally at least twice the cost of archived data.

Nation	Satellite and sensor	Resolution and coverage	Cost (archive ⁶⁰)	Feature
		60×60 km ²	USD 0.02/km ²	
India	IRS-P2 LISS-III & AWIFS	23.5 and 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/UK	DMC	32 m 160×660 km ²	EUR 3000/scene EUR 0.03/km ²	Commercial; Brazil uses alongside Landsat data.
France	SPOT-5 HRVIR	5–20 m 60×60 km ²	EUR 2000/scene EUR 0.5/km ²	Commercial; Indonesia and Thailand use alongside Landsat data.

Table 70: Example of a Potential Land-use Change Matrix

	Initial	Forest Land				
Final		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 71: Example of a Land Use/Land Cover Change Matrix

		Initial	Forest Land											Final area	
			Old growth forests		Degraded old growth forest			Secondary forest			Plantations				
Final			Intact	Managed	Initial	Intermediate	Advanced	Initial	Intermediate	Advanced	Young	Mid	Mature		
			Forest Land	Old-growth	Intact	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

TABLE 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 row totals show net conversion of each LU/LC-class.
- “Initial” indicates the area of the LU/LC class at the start date of the assessment period, 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 during the period assessed.

Table 72: Approximate Values of Daily Biomass Intake (d.m. dry mass) for Different Type of Animals⁶¹

Animal Type		Daily Feed Intake (MJ/head/day)	Daily Biomass Intake (kg d.m./head/day)
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).

⁶¹ Taken from AR-AM0003, v2

A4 Box 1: Geomod

Geomod is a land use land cover change simulation model implemented in TerrSet, a GIS software developed by Clark University (Brown et al., 2007; Pontius et al., 2001). Geomod has been used frequently to analyze baseline scenarios of deforestation at the continental scale for Africa, Asia and Latin America; at the country scale for Costa Rica and India; and at local scales within India, Egypt, the USA 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 may 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 start date. For example, Geomod's deforestation risk maps have relatively high values at locations that have biogeophysical attributes similar to those of deforested land (= "developed land" in Geomod's terminology) at the start date, and relatively low values at locations that have biogeophysical attributes similar to those of forested land ("non-developed" land) at the start date.

A4 Box 2: Example of simple error propagation analysis (Tier I method; Brown et al., 2007)

Carbon Pool	Average Carbon Stock (t C/ha)	95% CL (t C/ha)
Aboveground biomass	113	11
Dead wood	18	3
Litter	7	2

Therefore, the total stock is 138 t C/ha and the uncertainty = $\sqrt{11^2 + 3^2 + 2^2} = 11.6$ t C/ha

	Mean	95% CL	Uncertainty %
Area (ha)	8564	1158	14
Carbon stock (t C/ha)	138	11.6	8

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Table		Ex Ante	Ex Post	
		At validation	At verification	At baseline update
Table 13	Annual Areas Deforested Per Forest Class <i>icl</i> Within the Reference Region(baseline activity data per forest class)	Y		Y
Table 14	Annual Areas Deforested Per Forest Class <i>icl</i> Within the Project Area in the Baseline Case (Baseline Activity Data Per Forest Class)	Y	Y	Y
Table 15	Annual Areas Deforested Per Forest Class <i>icl</i> Within the Leakage Belt in the Baseline Case (Baseline Activity Data Per Forest Class)	Y	Y	Y
Table 16	Zones of the Reference Region Encompassing Different Combinations of Potential Post-Deforestation LU/LC Classes	Y		Y
Table 17	Annual Areas Deforested in Each Zone Within the Reference Region in the Baseline Case (Baseline Activity Data Per Zone)	Y	Y	Y
Table 18	Annual Areas Deforested in Each Zone Within the Project Area in the Baseline Case (Baseline Activity Data Zone)	Y	Y	Y
Table 19	Annual Areas Deforested in Each Zone Within the Leakage Belt in the Baseline Case (Baseline Activity Data Per Zone)	Y	Y	Y
Table 20	Baseline Activity Data for LU/LC Change Categories (<i>ct</i>) in the Reference Region	Y-M2,ct		Y-M2,ct
Table 21	Baseline Activity Data For LU/LC Change Categories (<i>ct</i>) in the Project Area	Y-M2,ct	Y-M2,ct	Y-M2,ct
Table 22	Baseline Activity Data For LU/LC Change Categories (<i>ct</i>) in the Leakage Belt	Y-M2,ct	Y-M2,ct	Y-M2,ct
Table 23	Carbon Stocks Per Hectare of Initial Forest Classes <i>icl</i> Existing in the Project Area and Leakage Belt – Estimated Values	Y		Y

Table		Ex Ante	Ex Post	
		At validation	At verification	At baseline update
Table 24	<i>Cwpicl</i> Components Summed In			
Table 25	Carbon Stocks Per Hectare of Initial Forest Classes <i>icl</i> Existing in the Project Area and Leakage Belt – Values After Discounting for Uncertainty	Y		Y
Table 26	Long-Term (20-Year) Average Carbon Stocks Per Hectare of Post-Deforestation LU/LC Classes Present in the Reference Region	Y		Y
Table 27	Long-Term (20-Year) Area-Weighted Average Carbon Stock Per Zone	Y		Y
Table 28	Potential Land Use and Land Cover Change Matrix	Y-M2,ctz		Y-M2,ctz
Table 29	List of Land Use and Land Cover Change Categories (<i>ctz</i>)	Y-M2,ctz		Y-M2,ctz
Table 30	Annual Areas Deforested in Each Category <i>ctz</i> Within the Reference Region in the Baseline Case (Baseline Activity Data Per Category <i>ctz</i>)	Y-M2,ctz		Y-M2,ctz
Table 31	Annual Areas Deforested in Each Category <i>ctz</i> Within the Project Area in the Baseline Case (Baseline Activity Data Per Category <i>ctz</i>)	Y-M2,ctz	Y-M2,ctz	Y-M2,ctz
Table 32	Annual Areas Deforested in Each Category <i>ctz</i> Within the Leakage Belt Area in the Baseline Case (Baseline Activity Data Per Category <i>ctz</i>)	Y-M2,ctz	Y-M2,ctz	Y-M2,ctz
Table 33	Emission Factors for Initial Forest Classes <i>icl</i> (Method 1)	Y-M1		Y-M1
Table 34	Emission Factors for Land Use Change Categories (<i>ct</i> or <i>ctz</i>) (Method 2)	Y-M2,ct Y-M2,ctz		Y-M2,ct Y-M2,ctz

Table		Ex Ante	Ex Post	
		At validation	At verification	At baseline update
Table 35	Baseline Carbon Stock Change for Selected Carbon Pools in the Reference Region (Method 1)	(Y-M1)		(Y-M1)
Table 36	Baseline Carbon Stock Change for Selected Carbon Pools in the Project Area (Method 1)	Y-M1	Y-M1 (A)	Y-M1
Table 37	Baseline Carbon Stock Change for Selected Carbon Pools in the Leakage Belt (Method 1)	(Y-M1)	Y-M1 (A)	(Y-M1)
Table 38	Baseline Carbon Stock Change for Selected Carbon Pools in the Reference Region (Method 2)	(Y-M2)		(Y-M2)
Table 39	Baseline Carbon Stock Change for Selected Carbon Pools in the Project Area (Method 2)	(Y-M2)	(Y-M2) (A)	(Y-M2)
Table 40	Baseline Carbon Stock Change in the Leakage Belt (Method 2)	(Y-M2)	(Y-M2) (A)	(Y-M2)
Table 41	Parameters Used to Calculate Non-CO ₂ Emissions from Forest Fires	Y*	Y*	Y*
Table 42	Baseline Non-CO ₂ Emissions from Forest Fires in the Project Area	Y*	Y* (A)	Y*
Table 43	Ex Ante Estimated Actual Carbon Stock Decrease Due to Planned Deforestation in the Project Area	Y*	Y*	Y*
Table 44	Ex Ante Estimated Actual Carbon Stock Decrease Due to Planned Logging Activities in the Project Area	Y*	Y*	Y*
Table 45	Ex Ante Estimated Actual Carbon Stock Decrease Due to Planned Fuel-Wood Collection and Charcoal Production in the Project Area	Y*	Y*	Y*
Table 46	Total Ex Ante Carbon Stock Decrease Due to Planned Activities in the Project Area	Y*	Y*	Y*
Table 47	Ex Ante Estimated Net Carbon Stock Change in the Project Area Under the Project Scenario	Y	Y	Y

Table		Ex Ante	Ex Post	
		At validation	At verification	At baseline update
Table 48	Total Ex Ante Estimated Actual Emissions of Non-CO ₂ Gases Due to Forest Fires in the Project Area	Y*	Y*	Y*
Table 49	Total Ex Ante Estimated Actual Net Carbon Stock Changes and Emissions of Non-CO ₂ Gases in the Project Area	Y	Y	Y
Table 50	Categories Subject to MRV	I		
Table 55	Ex Ante Estimated Carbon Stock Change in Leakage Management Zones in the Baseline Case	Y*	Y*	Y*
Table 56	Ex Ante Estimated Carbon Stock Change in Leakage Management Zones in the Project Case	Y*	Y*	Y*
Table 57	Ex Ante Estimated Net Carbon Stock Change in Leakage Management Zones	Y*	Y*	Y*
Table 58	Parameters Used for the Ex Ante Estimation of GHG Emissions from Grazing Activities	Y*	Y*	Y*
Table 59	Ex Ante Estimation of Leakage Emissions Above the Baseline from Grazing Animals in Leakage Management Zones	Y*	Y*	Y*
Table 60	Ex Ante Estimated Total Emissions Above the Baseline from Leakage Prevention Activities	Y*	Y*	Y*
Table 61	Ex Ante Estimated Leakage due to Activity Displacement	Y	Y	Y
Table 62	Ex Ante Estimated Total Leakage	Y	Y	Y
Table 64	Ex Ante Estimated Net GHG Emission Reductions: (Δ REDDt) and Verified Carbon Units (VCUt)	Y	Y	Y

TABLE NOTES

I Informative

Y	Yes, to be prepared
Y-M1	Yes, to be prepared where Method 1 (activity data per class) is used
Y-M2,ct	Yes, to be prepared where Method 2 (activity data per category ct) is used
Y-M2,ctz	Yes, to be prepared where Method 2 (activity data per category ctz) is used
()	Optional
*	To be prepared only where applicable
(A)	Actual changes instead of baseline changes

APPENDIX 7: DOCUMENT HISTORY

Version	Date	Comment
v1.0	12 Jun 2011	Initial version released.
V1.1	3 Dec 2012	<p>The methodology was revised to account for the decay of carbon from the belowground biomass, dead wood, soil carbon and medium-term harvested wood products pools. Revisions were made to Section 6.1.2 and Appendix 3.</p> <p>Additional revisions have also been incorporated into the methodology. Specifically, litter is included as an optional pool, sampling techniques are provided as an option for developing land use/land cover maps, the steps to analyze deforestation constraints are removed and a process to project future land use/land cover with zones is provided.</p> <p>The following minor updates have also been incorporated into the methodology:</p> <ul style="list-style-type: none"> • The word “guidelines” when referring to Jurisdictional and Nested REDD was changed to “requirements.” • Equations 6.a, 6.b and 6.c were corrected to avoid negative areas. • Equations 7.b and 12.c were corrected (“e” is Euler’s Number). • The minimum threshold requirements for the figure of merit (FOM) were changed and made consistent with the corresponding module of VM0007. • The definition of the minimum mapping unit was updated to be consistent with the definition found in the VCS JNR Requirements. • An error was corrected in Equation A3-17 (the factor 44/12 to convert tonnes of C to tonnes of CO_{2e} was missing).
V1.2	18 Dec 2023	<p>Incorporated the 13 December 2014 erratum regarding the omission of error propagation (OBox 2) and the 3 November 2017 clarification regarding post-deforestation carbon stock increase (former Section 6.1, current Section 6.6.2)</p> <p>Incorporated procedures for bias correction (Section 8.1.2)</p> <p>Excluded carbon stock enhancement.</p> <p>Added a requirement to determine the most plausible baseline scenario to align with the VCS Methodology Requirements and applicability conditions of VT0001 (Section 6.1).</p> <p>Added a stepwise process to test significance (Appendix 2)</p> <p>Excluded the modeling approach to project future deforestation</p> <p>Updated requirements to delineate the reference region (Section 5.1.1).</p> <p>Updated:</p> <ul style="list-style-type: none"> • Utilization of the most recent VCS Methodology Template to facilitate reporting

Version	Date	Comment
		<ul style="list-style-type: none">• References for the duration of baseline validity and historical reference periods to the <i>VCS Standard</i> and <i>VCS Methodology Requirements</i>, respectively• Document references Made minor editorial corrections.