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Methodology for Estimating Reductions of Greenhouse Gases Emissions from *Frontier Deforestation*

Manaus, 17 May 2010

Proposed

Methodology for Estimating Reductions of GHG Emissions from *Frontier Deforestation*

REDD-NM-002

Source

This methodology is based on the draft REDD-PD for the "Reserva do Juma Conservation Project" in Amazonas (Brazil), whose *baseline* study, monitoring and project design documents were prepared by IDESAM, the Amazonas Sustainable Foundation (FAS) and the Government of Amazonas (SDS/SEPLAN-AM), with inputs and review from a selected group of experts and scientists in Brazil. The methodology is an adaptation to "*Frontier Deforestation*" of the methodology for "*Mosaic Deforestation*" developed by the BioCarbon Fund.

Scope

The methodology is for estimating and monitoring greenhouse gas (GHG) emissions of project activities that reduce frontier *deforestation*[1].

The *project area* in the *baseline* case may or may not be a mosaic of old growth-forests, degraded (and perhaps still degrading) forests, and secondary (growing) forests with more than 10 years of age at the project start date. Forests in the *baseline* case may or may not be subject to logging for timber, fuel wood collection or charcoal production.

The *project activity* may or may not involve logging for timber, fuel wood collection or charcoal production. Project proponents are not seeking credits for avoided degradation[2], and therefore:

- GHG emission reductions in areas that would be degraded (but not deforested) in the *baseline* case within the *project area* are not quantified nor claimed; and
- Leakage from avoided degradation in areas that would be degraded (but not deforested) in the *baseline* case which may occur as a consequence of the REDD *project activity* within the *project area* is assumed to be similar to the avoided degradation and must not be quantified.

The possible categories covered by this methodology are represented with the letters **A** to **H** in Table 1.

1 The most recent VCS definition of "*frontier deforestation*" shall be used in applying this methodology. *Frontier deforestation* is where humans and their infrastructure are encroaching into areas with relatively little preexisting human activity. It is often linked to infrastructure development and it happens where poor legislation enforcement, prices for agricultural commodities, speculation for land titling and other drivers provide incentives to farmers and ranchers to clear the *forest* as it becomes more accessible.

2 If they do, an approved VCS methodology for Improved Forestry Management (IFM) shall be applied in the strata of the *project area* where degradation is reduced and the *baseline* is not *deforestation*.

2

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**[1]	**D**[1]
		Degraded and still degrading	**E**[1]	**F**[1]
		Secondary growing	**G**[1]	**H**[1]
	No-deforestation[2]	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

Notes:

1) Accounting for carbon stock increase in the project scenario is optional and can conservatively be omitted.
2) If the *baseline* is not *deforestation*, the change in carbon stocks is not covered in this methodology.

Acknowledgements

Idesam and FAS acknowledge the leading author of this methodology, Mr. Lucio Pedroni (Carbon Decision International), and the BioCarbon Fund for publishing the methodology for "*mosaic deforestation*" which greatly facilitated the development of this methodology.

3

TABLE OF CONTENTS

5

6

SUMMARY

This methodology is for *project activities* that reduce emissions of greenhouse gases (GHG) from *frontier deforestation* and, where significant and measurable, increase carbon stocks of degraded and secondary forests that would be deforested in the absence of the *project activity*.

The methodology is applicable under the following conditions:

a) *Deforestation* is linked to infrastructure development, which makes the *forest* accessible to *deforestation* agents, or to the expansion of the agricultural frontier.

b) *Baseline* activities that may be displaced by the REDD *project activity* include logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities.

c) The *project area* can include different types of *forest*, such as old-growth *forest*, degraded *forest*, secondary *forest*s, planted *forests* and agro-forestry systems meeting the definition of *"forest"*.

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

e) Changes in the ground water table are excluded in both the *baseline* and project scenarios or must be the same under the two scenarios.

The methodology requires using existing *deforestation baseline*s if these are VCS or UNFCCC approved or meet certain applicability criteria which are outlined in the methodology. If such *baseline*s do not exist or cannot be applied according to the applicability criteria, a spatially explicit *baseline* projection must be presented at the time of validation.

Leakage in this methodology is subject to monitoring, reporting, verification (MRV) and accounting, except when the *project area* is located within a broader sub-national or national area that is monitoring, reporting, verifying (MRV) and accounting emissions from *deforestation* under an VCS or UNFCCC acknowledged program, in which case activity displacement leakage can be ignored because any change in carbon stocks or increase in GHG emissions outside the *project area* is already duly accounted in the broader program.

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

- The *reference region* is the analytical domain from which information on historical *deforestation* is extracted and projected into the future to spatially locate the area that will be deforested in the *baseline* case and to quantify the carbon stock changes and GHG emissions that are expected to occur during the project crediting period in the *project area*.

7

- The *project area* is the area under the control of the project participants in which the REDD *project activity* will be implemented and GHG emission reductions accounted.
- The leakage belt is the area where activity displacement leakage will be monitored and it must be defined only if MRV and accounting for activity displacement leakage is required[3]. The leakage only includes areas that would remain forested in absence of the REDD *project activity* as predicted by the *baseline* projections.
- Leakage management areas are those areas specifically dedicated to implement activities that reduce the risk of activity displacement leakage, such as enhanced crop-land and grazing land management, agro-forestry, silvo-pastoral activities and reforestation activities.

The *baseline* projections of the *reference region* and *project area* must be revisited at least every 10 years and adjusted, as necessary, based on land-use and land-cover changes observed during the past period, updated information on agents, drivers and underlying causes of *deforestation* and new data on all variables included in the *baseline deforestation* model. The period of time during which a validated *baseline* must not be reassessed is called "fixed *baseline* period" in this methodology.

Emissions of non-CO_2 gases in the *baseline* are conservatively omitted, except CH_4 and N_2O emissions from biomass burning, which can be counted when *fire* is the main technology used to deforest and when the project proponent considers that ignoring this source of emission would substantially underestimate *baseline* GHG emissions.

The methodology considers two potential sources of leakage:

(i) Activity displacement leakage; and

(ii) Increased emissions due to leakage prevention measures.

If activity displacement leakage must be quantified and accounted for, two approaches can be used: (i) a 40% discount on the estimated GHG emission reductions within the *project area*[4]; or (ii) monitoring of *deforestation*, associated carbon stock changes, and GHG emissions in the leakage belt area.

If leakage prevention measures include tree planting, agricultural intensification, fertilization, fodder production and/or other measures to enhance cropland and grazing land areas outside the *project area*, then the increase in GHG emissions associated with these activities is estimated and subtracted from the project's net anthropogenic emissions reductions.

Any decrease in carbon stock or increase in GHG emissions attributed to the *project activity* must be accounted when it is significant, otherwise it can be neglected. Significance in this

3 A leakage belt is not required if the method chosen for quantifying activity displacement leakage is the time discount approach. See Step 8.

4 The discount factor is based on Fearnside (2007) and the following assumptions: 100% of the reduced *deforestation* is displaced in the short term; in the long term (100 years) more forest is conserved than in the *baseline* case, as the basic effect of the *project activity* is to reduce the area available for *deforestation*; a discount rate of 1% to account for the effect of time.

8

methodology is assessed using the most recent CDM-approved version of the "Tool for testing significance of GHG emissions in A/R CDM project activities"[5].

[5] Available at http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

9

METHODOLOGY DESCRIPTION

Part 1 - Applicability conditions and additionality

1 Applicability conditions

This methodology is applicable to *project activities* that reduce greenhouse gas (GHG) emission from *frontier deforestation* and, where relevant and measurable, enhance carbon stocks of degraded and secondary forests that would be deforested in absence of the *project activity*. *Baseline* and project activities may include harvesting of timber, fuel-wood collection and charcoal production[6].

The methodology is applicable under the following conditions:

a) *Deforestation* is linked to infrastructure development, which makes the *forest* accessible to *deforestation* agents.

b) *Baseline* activities that may be displaced by the REDD *project activity* include logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities.

c) The *project area* can include different types of *forest*, such as old-growth *forest*, degraded *forest*, secondary *forest*s, planted *forests* and agro-forestry systems meeting the definition of *"forest"*.

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

e) Changes in the ground water table are excluded in both the *baseline* and project scenarios or must be the same under the two scenarios.

Demonstrate that the methodology is applicable to the proposed REDD *project activity*.

2 Additionality[7]

The following steps are used to demonstrate additionality:

Step 0. Preliminary screening based on the starting date of the REDD *project activity*;

Step 1. Identification of alternative land use scenarios to the REDD *project activity*;

Step 2. Investment analysis to determine that the proposed *project activity* is not the

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

[7] This section has been taken and partially adapted from the methodology proposed by Avoided *Deforestation* Partners. For further clarification, access http://www.adpartners.org/initiatives_redd.html.

10

most economically or financially attractive of the identified land use scenarios; or

Step 3. Barriers analysis; and

Step 4. Common practice analysis.

The proposed REDD *project activity* within the project boundary shall not violate of any applicable law even if the law is not enforced.

The demonstration of additionality shall be consistent with the selected *baseline* scenario and the proposed REDD *project activity*.

Step 0. Preliminary screening based on the starting date of the REDD *project activity*

The earliest start date of the proposed REDD *project activity* is January 1st, 2002. However, the start date can be earlier than January 1st, 2002, provided the following conditions are met:

- Project validation and verification under the VCS has been completed by October 1st, 2010;
- The project proponent can verifiably demonstrate that the *project activity* was designed and implemented as a climate change mitigation project from its inception. This evidence shall be based on (preferably official, legal and/or other corporate) documentation that was available to third parties at, or prior to, the start of the *project activity*; and
- Prior to January 1st, 2002, the project applied an externally reviewed methodology and engaged independent carbon monitoring experts to assess and quantify the project's *baseline* scenario and net emissions reductions or removals.

Step 1. Identification of alternative land use scenarios to the proposed REDD *project activity*

Sub-step 1.a Identify credible alternative land use scenarios to the proposed REDD *project activity*

Identify credible land-use scenarios that would have occurred within the project boundary in the absence of the proposed REDD *project activity*. The scenarios should be feasible for the project proponents or similar project developers taking into account relevant national and/or sectoral policies and circumstances, such as historical land uses, practices and economic trends. The identified land use scenarios shall at least include:

- Projected *deforestation* and/or forest degradation as estimated using the *baseline* methodology; or
- Avoiding *deforestation* and/or forest degradation of the land within the project boundary in absence of the proposed REDD *project activity*; as well as,

11

- If applicable, activities reducing *deforestation* and/or degradation within the project boundary resulting from:
    - Legal requirements; or
    - Extrapolation of observed activities stopping *deforestation* and/or forest degradation in the *reference region* in the 10-year period before the start date of the proposed REDD *project activity*.

Use historical land use records, field surveys, literature, expert opinions and/or other appropriate sources of information, including Participatory Rural Appraisal (PRA)[8].for identifying credible alternative land-use scenarios.

Existing land-uses within the boundary of the proposed REDD *project activity* or the *reference region* that existed at some time in the 10-year period prior to the start date of the proposed REDD *project activity* may be deemed realistic and credible. For all other land use scenarios, credibility shall be justified. The justification shall include elements of spatial planning information (if applicable) or legal requirements and may include assessment of economical feasibility of the proposed land use scenario.

Outcome of sub-step 1.a: List of credible alternative land use scenarios that would have occurred within the *project area* in the absence of the proposed REDD *project activity*.

Sub-step 1.b Consistency of alternative land use scenarios with applicable and enforced laws and regulations

Demonstrate that all alternative land use scenarios identified in the sub-step 1a are in compliance with all applicable legal and regulatory requirements.

- If an alternative does not comply with all applicable laws and regulations, then show that, based on an examination of current practice in the region in which the law or regulation applies, those legal or regulatory requirements are systematically not enforced and that non-compliance is widespread, i.e. prevalent on at least 30% of the area of the smallest administrative unit that encompasses the *project area*;
- Remove from the land use scenarios identified in the sub-step 1.a, any land use scenarios which are not in compliance with applicable mandatory laws and regulations unless it can be shown these land use scenarios result from systematic lack of

[8] Participatory rural appraisal (PRA) is an approach to the analysis of local problems and the formulation of tentative solutions with local stakeholders. It makes use of a wide range of visualization methods for group-based analysis to deal with spatial and temporal aspects of social and environmental problems. This methodology is, for example, described in:
- Chambers R (1992): Rural Appraisal: Rapid, Relaxed, and Participatory. Discussion Paper 311, Institute of Development Studies, Sussex;
- Theis J, Grady H (1991): Participatory rapid appraisal for community development. Save the Children Fund, London.

12

enforcement of applicable laws and regulations.

Outcome of sub-step 1.b: List of plausible alternative land use scenarios to the REDD *project activity* that are in compliance with mandatory legislation and regulations taking into account their enforcement in the region or country and any VCS decisions on national and/or sectoral policies and regulations.

- If the list resulting from the sub-step 1.b is empty or contains only one land use scenario, then the proposed REDD *project activity* is not additional.
- If the list resulting from the sub-step 1.b contains more than one land use scenario, proceed to Step 2 (Investment analysis) or Step 3 (Barrier analysis), as it is necessary to undertake at least one of these to assess and demonstrate additionality.

Step 2. Investment analysis

Determine whether the proposed REDD *project activity*, without carbon market-related revenues, is economically or financially less attractive than at least one of the plausible land use alternatives listed in sub-step 1.b. Investment analysis may be performed as a stand-alone additionality analysis or in connection to the barrier analysis (Step 3). To conduct the investment analysis, use the following sub-steps:

Sub-step 2.a Determine appropriate analysis method

Determine whether to apply simple cost analysis, investment comparison analysis or benchmark analysis. If the REDD *project activity* generates no financial or economic benefits other than carbon market-related income, then apply the simple cost analysis (Option I). Otherwise, use the investment comparison analysis (Option II) or the benchmark analysis (Option III). Note, that Options I, II and III are mutually exclusive, hence, only one of them can be applied.

Outcome of sub-step 2.a: Selection and justification of the appropriate analysis method

Sub-step 2.b Apply the selected analysis method

Option I: Simple cost analysis

Document the costs associated with the REDD *project activity* and demonstrate that the activity produces no financial benefits other than carbon market-related income.

If activities stopping *deforestation* and/or forest degradation in the *project area* or in the *reference region* occurring in the 10-year period before the start date of the proposed REDD *project activity* have disappeared, the project proponents shall identify incentives/reasons/actions that allowed for the past activities stopping *deforestation* and/or forest degradation and demonstrate that the current legal/financial or other applicable regulations or socio-economical or ecological or other local conditions have changed to an

13

extent that justifies the conclusion that the activity produces no financial benefits other than carbon market-related income.

- If it is concluded that the proposed REDD *project activity* produces no financial benefits other than carbon market-related income then proceed to Step 4 (Common practice analysis).
- If it is concluded that the proposed REDD *project activity* produces financial benefits other than carbon market-related income then simple cost analysis is not applicable and Option II or III shall be used.

Option II: Investment comparison analysis

Identify the financial indicator, such as IRR[9], NPV, payback period, cost-benefit ratio most suitable for the project type and decision-making context.

Option III: Apply benchmark analysis

Identify the financial indicator, such as IRR[10], NPV, payback period, cost-benefit ratio, or other (e.g. required rate of return, RRR) related to investments in agriculture or forestry, bank deposit interest rate corrected for risk inherent to the project or the opportunity costs of land, such as any expected income from land speculation) most suitable for the project type and decision context. The benchmark is to represent standard returns in the market, considering the specific risk of the project type, but not linked to the subjective profitability expectation or risk profile of a particular project developer. Benchmarks can be derived from:

- Government bond rates, increased by a suitable risk premium to reflect private investment and/or the project type, as substantiated by an independent (financial) expert;
- Estimates of the cost of financing and required return on capital (e.g. commercial lending rates and guarantees required for the country and the type of *project activity* concerned), based on bankers views and private equity investors/funds' required return on comparable projects; or,
- A company internal benchmark (weighted average capital cost of the company) if there is only one potential project developer (e.g. when the proposed project land is owned or otherwise controlled by a single entity, physical person or a company, who is also the project developer). The project developers shall demonstrate that this

[9] For the investment comparison analysis, IRRs can be calculated either as project IRRs or as equity IRRs. Project IRRs calculate a return based on project cash outflows and cash inflows only, irrespective the source of financing. Equity IRRs calculate a return to equity investors and therefore also consider amount and costs of available debt financing. The decision to proceed with an investment is based on returns to the investors, so equity IRR will be more appropriate in many cases. However, there will also be cases where a project IRR may be appropriate.

[10] For the benchmark analysis, the IRR shall be calculated as project IRR. If there is only one potential project developer (e.g. when the *project activity* upgrades an existing process), the IRR shall be calculated as equity IRR.

14

benchmark has been consistently used in the past, (i.e. that project activities under similar conditions developed by the same company used the same benchmark).

Calculation and comparison of financial indicators (only applicable to options II and III)

Calculate the suitable financial indicator for the proposed REDD *project activity* without the financial benefits from carbon finance and, in the case of Option II above, for the other land use scenarios. Include all relevant costs (including, for example, the investment, operations and maintenance costs), and revenues (excluding carbon market revenues, but including subsidies/fiscal incentives where applicable), and, as appropriate, non-market cost and benefits in the case of public investors.

Present the investment analysis in a transparent manner and provide all the relevant assumptions in the VCS PD, so that a reader can reproduce the analysis and obtain the same results. Clearly present critical economic parameters and assumptions (such as capital costs, lifetimes, and discount rate or cost of capital). Justify and/or cite assumptions in a manner that can be validated by the validator. In calculating the financial indicator, the project's risks can be included through the cash flow pattern, subject to project-specific expectations and assumptions (e.g. insurance premiums can be used in the calculation to reflect specific risk equivalents).

Assumptions and input data for the investment analysis shall not differ across the *project activity* and its alternatives, unless differences can be well substantiated.

In the VCS PD submitted for validation, present a clear comparison of the financial indicator for the proposed REDD *project activity* without the financial benefits from carbon finance and:

- **Option II** (investment comparison analysis): If one of the plausible alternative land use scenarios has the better indicator (e.g. higher IRR), then the REDD *project activity* cannot be considered as financially attractive; or
- **Option III** (benchmark analysis): If the REDD *project activity* has a less favorable indicator (e.g. lower IRR) than the benchmark, then the REDD *project activity* cannot be considered as financially attractive.

Outcome of sub-step 2.b:

- If it is concluded that the proposed REDD *project activity* without the financial benefits from carbon finance is not the most financially attractive option then proceed to Step 2.c (Sensitivity Analysis).
- If it is concluded that the proposed REDD *project activity* is likely to be financially more attractive than at least one plausible alternative land use, then the *project activity* cannot be considered additional by means of financial analysis. Optionally proceed to Step 3 (Barrier analysis) to prove that the proposed *project activity* faces barriers that do not prevent the *baseline* land use scenario(s) from occurring. If the Step 3 (Barrier analysis) is not employed then the *project activity* cannot be considered additional.

15

Sub-step 2.c Sensitivity analysis

Include a sensitivity analysis that shows whether the conclusion regarding the financial attractiveness is robust to reasonable variations in the critical assumptions. The investment analysis provides a valid argument in favor of additionality only if it consistently supports (for a realistic range of assumptions) the conclusion that the proposed REDD *project activity* without the financial benefits from carbon finance is unlikely to be financially attractive.

If activities stopping *deforestation* and/or forest degradation in the *project area* or *reference region* occurring in the 10-year period before the start date of the proposed REDD *project activity* have disappeared, the project proponents shall demonstrate that incentives/reasons/actions that allowed for the past activities have changed to an extent that affects the financial attractiveness of such activities in the *project area* without being registered as the REDD project.

Outcome of sub-step 2.c:

- If after the sensitivity analysis it is concluded that the proposed REDD *project activity* without the financial benefits from carbon finance is unlikely to be financially most attractive (Option II and Option III), then proceed directly to Step 4 (Common practice analysis).
- If after the sensitivity analysis it is concluded that the proposed REDD *project activity* is likely to be financially most attractive (Option II and Option III), then the *project activity* cannot be considered additional by means of financial analysis. Optionally proceed to Step 3 (Barrier analysis) to prove that the proposed *project activity* faces barriers that do not prevent the *baseline* land use scenario(s) from occurring. If the Step 3 (Barrier analysis) is not employed then the *project activity* cannot be considered additional.

Step 3. Barrier analysis

Barrier analysis may be performed as a stand-alone additionality analysis or as an extension of investment analysis.

If this step is used, determine whether the proposed *project activity* faces barriers that:

- Prevent the implementation of this type of proposed *project activity*; and
- Do not prevent the implementation of at least one of the alternative land use scenarios.

Use the following sub-steps:

Sub-step 3.a Identify barriers that would prevent the implementation of the type of proposed *project activity*

Establish that there are barriers that would prevent the implementation of the type of proposed *project activity* from being carried out if the *project activity* was not registered as a REDD

16

activity. The barriers should not be specific to the project proponents. Such barriers may include, among others:

- Investment barriers, other than the economic/financial barriers in Step 2 above, *inter alia*:
  - For REDD project activities undertaken and operated by private entities: Similar activities have only been implemented with grants or other non-commercial finance terms. In this context similar activities are defined as activities of a similar scale that take place in a comparable environment with respect to regulatory framework and are undertaken in the relevant geographical area;
  - Debt funding is not available for this type of *project activity*;
  - No access to international capital markets due to real or perceived risks associated with domestic or foreign direct investment in the country where the *project activity* is to be implemented, as demonstrated by the credit rating of the country or other country investment reports of reputed origin; and,
  - Lack of access to credit.
- Institutional barriers, *inter alia*:
  - Risk related to changes in government policies or laws; and,
  - Lack of enforcement of *forest* or land-use-related legislation.
- Technological barriers, *inter alia*:
  - Lack of access to planting materials (e.g. if plantations are a leakage avoidance strategy); and,
  - Lack of infrastructure for implementation of the technology.
- Barriers related to local tradition, *inter alia*:
  - Traditional knowledge or lack thereof, laws and customs, market conditions, practices; and,
  - Traditional equipment and technology.
- Barriers due to prevailing practice, *inter alia*:
  - The *project activity* is the "first of its kind": No *project activity* of this type is currently operational in the host country or region.
- Barriers due to social conditions, *inter alia*:
  - Demographic pressure on the land (e.g. increased demand on land due to population growth);
  - Social conflict among interest groups in the region where the project takes place;
  - Widespread illegal practices (e.g. illegal grazing, non-timber product extraction and tree felling);

17

  - Lack of skilled and/or properly trained labor force; and,
  - Lack of organization of local communities.

- Barriers relating to land tenure, ownership, inheritance, and property rights, *inter alia*:
  - Communal land ownership with a hierarchy of rights for different stakeholders limits the incentives to undertake REDD activity;
  - Lack of suitable land tenure legislation and regulation to support the security of tenure;
  - Absence of clearly defined and regulated property rights in relation to natural resource products and services; and,
  - Formal and informal tenure systems that increase the risks of fragmentation of land holdings.

The identified barriers are only sufficient grounds for demonstration of additionality if they would prevent potential project proponents from carrying out the proposed *project activity* if it was not expected to be registered as a REDD *project activity*.

Provide transparent and documented evidence, and offer conservative interpretations of this documented evidence, as to how it demonstrates the existence and significance of the identified barriers. Anecdotal evidence can be included, but this alone is insufficient proof of barriers. The type of evidence to be provided may include:

- Relevant legislation, regulatory information or environmental/natural resource management norms, acts or rules;
- Relevant (sectoral) studies or surveys (e.g. market surveys, technology studies, etc) undertaken by universities, research institutions, associations, companies, bilateral/multilateral institutions, etc;
- Relevant statistical data from national or international statistics;
- Documentation of relevant market data (e.g. market prices, tariffs, rules);
- Written documentation from the company or institution developing or implementing the REDD *project activity* or the REDD project developer, such as minutes from Board meetings, correspondence, feasibility studies, financial or budgetary information, etc.;
- Documents prepared by the project developer, contractors or project partners in the context of the proposed *project activity* or similar previous project implementations; and,
- Written documentation of independent expert judgments from agriculture, forestry and other land-use related Government / Non-Government bodies or individual experts, educational institutions (e.g. universities, technical schools, training centers), professional associations and others.

If activities stopping *deforestation* and/or forest degradation in the *project area* or *reference region* occurring in the 10-year period before the Project Start Date have disappeared, the

18

project proponent shall :

- identify incentives/reasons/actions/that allowed for the past activity; and,
- demonstrate that the current legal/financial or other applicable regulations or ecological or other local conditions have changed to the extent that they pose a barrier which allows for conclusion that repetition of the activity performed (without being registered as the REDD *project activity*) is not possible.

Outcome of sub-step 3.a: List of key barriers identified.

Sub-step 3b. Show that the identified barriers would not prevent the implementation of at least one of the alternative land use scenarios (except the proposed *project activity*)

If the identified barriers also affect other land use scenarios, explain how they are affected less strongly than they affect the proposed REDD *project activity*. In other words, explain how the identified barriers are not preventing the implementation of at least one of the alternative land use scenarios. Any land use scenario that would be prevented by the barriers identified in Sub-step 3a is not a viable alternative, and shall be eliminated from consideration. At least one viable land use scenario shall be identified.

Outcome of sub-step 3.b:

- If both Sub-steps 3a – 3b are satisfied, then proceed directly to Step 4 (Common practice analysis).
- If one of the Sub-steps 3a – 3b is not satisfied then the *project activity* cannot be considered additional by means of barrier analysis. Optionally proceed to Step 2 (Investment analysis) to prove that the proposed REDD *project activity* without the financial benefits from carbon markets is unlikely to produce economic benefit (Option I) or to be financially attractive (Option II and Option III). If the Step 2 (Investment analysis) is not employed then the *project activity* cannot be considered additional.

Step 4. Common practice analysis

The previous steps shall be complemented with an analysis of the extent to which similar activities stopping *deforestation* and forest degradation have already diffused in the geographical area of the proposed REDD *project activity*. This test is a credibility check to demonstrate additionality that complements the barrier analysis (Step 2) and the investment analysis (Step 3).

Provide an analysis as to which extent similar activities stopping *deforestation* and forest degradation to the one proposed as the REDD *project activity* have been implemented previously or are currently underway. Similar activities are defined as those which are of similar scale and take place in a comparable environment, *inter alia*, with respect to the regulatory framework and are undertaken in the relevant geographical area, subject to further

19

guidance by the underlying methodology. Other registered REDD project activities shall not be included in this analysis. Provide documented evidence and, where relevant, quantitative information. Limit your considerations to the 10-year period prior to the project start date.

If activities stopping *deforestation* and forest degradation similar to the proposed REDD *project activity* are identified, then compare the proposed *project activity* to the other similar activities and assess whether there are essential distinctions between them. Essential distinctions may include a fundamental and verifiable change in circumstances under which the proposed REDD *project activity* will be implemented when compared to circumstances under which similar activities were carried out. For example, barriers may exist, or promotional policies may have ended. If certain benefits rendered the similar forestation activities financially attractive (e.g., subsidies or other financial flows), explain why the proposed REDD *project activity* cannot use the benefits. If applicable, explain why the similar activities do or did not face barriers to which the proposed REDD *project activity* is subject.

Outcome of step 4: If Step 4 is satisfied, i.e. similar activities can be observed and essential distinctions between the proposed REDD *project activity* and similar activities cannot be made, then the proposed REDD *project activity* cannot be considered additional. Otherwise, the proposed REDD *project activity* is not the *baseline* scenario and, hence, it is additional.

20

Part 2 - Methodology steps for validation

The nine methodology steps that will lead the project to validation are summarized in Figure 1. In the Project Description (PD) refer to each of these steps and sub-steps using the same titles and numbers so that the application of the methodology can be validated transparently.

Figure 1. *Ex ante* methodology steps

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

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

↓

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

↓

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

↓

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

↓

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

↓

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

↓

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

↓

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

21

Step 1: Definition of boundaries

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

1.1 Spatial boundaries;

1.2 Temporal boundaries;

1.3 Carbon pools; and

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

1.1 Spatial boundaries

Define the boundaries of the following five spatial features:

1.1.1 *Reference region*;

1.1.2 *Project Area*;

1.1.3 Leakage belt;

1.1.4 Leakage management areas; and

1.1.5 *Forest*

The *reference region* is the largest unit of land and the *project area*, leakage belt and leakage management areas are subsets of the *reference region*. For each of these spatial features describe and justify the criteria used to define their spatial boundaries in the PD. Use appropriate sources of spatial data for each of these criteria, such as remotely sensed data, field information, and other verifiable sources of information.

Provide vector or raster files in a common projection and GIS software format in order in order to allow an unambiguous identification of the boundaries.

1.1.1 *Reference region*

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

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

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

1. If a sub-national or national *baseline* satisfying the applicability criteria listed in Table 2 exists, it must be used. In this case, the existing *baseline* will determine the boundary of the *reference region*.
2. If no such applicable sub-national or national *baseline* is available, the national and, where applicable, sub-national government shall be consulted to determine whether the

22

country or sub-national region has been divided in spatial units for which *deforestation baselines* will be developed following VCS or UNFCCC rules. If such divisions exist and are endorsed by the national or sub-national government, they must be used to determine the boundary of the *reference region*.

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

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

Table 2. Criteria determining the applicability of existing *baseline*s

	Applicability criteria
1	The existing *baseline* must cover a broader geographical region than the *project area*. If a leakage belt must be defined[1], the broader region must include the leakage belt.
2	The existing *baseline* must cover at least the duration of the first fixed *baseline* period and is not outdated[2].
3	The existing *baseline* must depict the location of future *deforestation* on a yearly base, unless methodology thresholds are met not requiring a spatial *baseline*.
4	The spatial resolution of the existing *baseline* must be equal to or finer than the minimum mapping unit of "forest land" that will be used for monitoring *deforestation* during the fixed *baseline* period.
5	If the existing *baseline* has been independently validated by a VCS accredited verifier, or is registered under a VCS acknowledged system, or has been established by the national or sub-national government having adopted a REDD scheme recognized by VCS or UNFCCC, an independent validation of the projection is not required and the existing projection must be used.
6	If requirement 5 (above) is not satisfied, methods used to develop the existing *baseline* must be transparently documented and be consistent with a VCS approved and applicable *baseline* methodology. In this case, an independent validation of the existing *baseline* is required.

Notes:

1. A leakage belt must be defined when the *project area* is not located within a broader sub-national or national area that is monitoring, reporting, verifying and accounting emissions from *deforestation* under a VCS or UNFCCC acknowledged program.
2. A *baseline* is considered outdated 10 years after its establishment.

23

The *reference region* may include one or several discrete areas. It should be larger[11] than the *project area* and include the *project area*. If the *project area* is a forest island (i.e. no surrounding forests exist), the *reference region* can be placed in a geographic area that does not include the *project area*, provided the conditions determining the likelihood of *deforestation* within the *project area* are similar or expected to become similar (during the crediting period) to those found within the *reference region*.

If the current situation within the *project area* is expected to change (e.g. because of population growth, infrastructure development or any other plausible reason), the *reference region* should be divided in *i* strata[12], each representing proxies for the chrono-sequence of current and future conditions within the *project area*.

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

- **Agents and drivers of *deforestation*** existing or expected to exist within the *project area* must exist elsewhere in the *reference region*. If the *reference region* includes agent groups that are not present in the *project area* and that may not encroach into the *project area* in the future, the spatial projection of future *deforestation* (Step 4.2) must include spatial variables that constrain the migration of such agents into the *project area*. For instance, if the expansion of the *deforestation* frontier within the boundary of the *project area* is linked to population growth of small farmers practicing subsistence agriculture and fuel-wood collection on land that is considered marginal for mechanized agriculture, at least one map representing unfavorable conditions for mechanized agriculture (e.g. soil type, slope, etc.) must be included in the spatial analysis of Step 4.2.
- **Landscape configuration and ecological conditions:** At least three of the following four conditions must be satisfied:
    1. **Forest/vegetation classes:** At least 90% of the *project area* must have forest classes or vegetation types that exist in at least 90% of the rest of the *reference region*.
    2. **Elevation:** At least 90% of the *project area* must be within the elevation range of at least 90% of the rest of the *reference region*.

[11] The exact ratio between *reference region* area and project depends on the particular regional and project circumstances. The *reference region* may encompass from just the *project area* (e.g. in case of small isolated forests or islands) up to a broader sub-national category (e.g. a larger watershed, a province or a state) or even the entire country. Where a *project activity* deals with an entire island, the *reference region* may include other islands with similar conditions. [12] Note that stratification can be either static (i.e. with fixed boundaries), or dynamic (i.e. with shifting boundaries, according to modeled changes at the level of driver variables such as population, infrastructure and other to be determined by the project proponent)

[12] Note that stratification can be either static (i.e. with fixed boundaries), or dynamic (i.e. with shifting boundaries, according to modeled changes at the level of driver variables such as population, infrastructure and other to be determined by the project proponent)

24

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

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

- **Socio-economic and cultural conditions:** The following conditions must be met:
  - **Legal status of the land**: The legal status of the land (private, forest concession, conservation concession, etc.) in the *baseline* case within the *project area* must exist elsewhere in the *reference region*. If the legal status of the *project area* is a unique case, demonstrate that this legal status is not biasing the *baseline* of the *project area* (e.g. by demonstrating that access to the land by *deforestation* agents is similar to other areas with a different legal status).
  - **Land tenure**: The land-tenure system prevalent in the *project area* in the *baseline* case is found elsewhere in the *reference region*.
  - **Land use:** Current and projected classes of land-use in the *project area* are found elsewhere in the *reference region*.
  - **Enforced policies and regulations**: The *project area* shall be governed by the same policies, legislation and regulations that apply elsewhere in the *reference region*.

1.1.2 *Project area*

The *project area* is the area or areas of land under the control of the project participants on which the project proponent will undertake the *project activities* that reduce emissions from *deforestation*. To demonstrate control on the land, legal documents demonstrating land ownership must be collected (e.g. land title from the public registry or other legally valid documents in the country), as well as documents demonstrating that the land owner(s) agree with the project activities in their lands. If the some of the boundaries of ownership are unclear, these must be ratified in association with the interested parties (see Mustalahti, 2008).

At the project start date, the *project area* must include only forest land.

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. Such areas will not generate carbon credits, but they may be included if the project proponent considers that future *baseline* assessments, (which have to be carried out at least every 10 years,) are likely to indicate that a future *deforestation* threat will exist, although the demonstration is not possible at the time of validation.

Following VCS 2007.1 (2008 p.16-17), new discrete units of land (referred to as "new *project area*") may be integrated into an existing *project area* if included in the monitoring report for the first verification. After the first verification, the boundary of the *project area* remains fixed for the rest of the crediting period.

25

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

- Name (or names, as appropriate) of the *project area*.
- Physical boundary of each discrete area of land included in the *project area* (using appropriate GIS software file formats).
- Description of current land-tenure and ownership, including any legal arrangement related to land ownership and the REDD *project activity*.
- List of the project participants and brief description of their roles in the proposed REDD *project activity*.

1.1.3 Leakage belt

If the *project area* is located within a sub-national area or a country having a UNFCCC or VCS-approved monitoring, verification, reporting (MRV) and accounting scheme for emissions from *deforestation*, activity displacement leakage must not be assessed and a leakage belt is not required, because any decrease in carbon stocks or increase in GHG emissions outside the *project area* is already measured, reported, verified and accounted at the broader scale[13] of the sub-national area or country. In all other cases, activity displacement leakage must be accounted. Two approaches can be used to do such accounting:

- Approach 1: Time discount approach (See Step 8.2)
- Approach 2: Monitoring of the leakage belt area.

If approach 2 is chosen, a leakage belt area must be defined.

The leakage belt is the land area or land areas surrounding or adjacent to the *project area* in which *baseline* activities could be displaced due to the project activities implemented in the *project area*. The leakage belt area is not necessarily connected to the boundary of the *project area*, as it must be placed at forested locations that remain forested at end of the crediting period according to the *baseline* projections.

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

- Option I: Opportunity Cost Analysis.
- Option II: Mobility Analysis.

Option I: Opportunity Cost Analysis

This option is applicable where economic profit is an important driver of *deforestation*. To demonstrate that Option I is applicable, use historical records, i.e. demonstrate that at least 80% of the area deforested in the *reference region* during the historical reference period has

[13] In such cases, the sub-national or national government may charge a leakage tax to the project, depending on national and sub-national policies and regulations; however the payment of such a tax shall not be a validation requirement.

26

occurred at locations where deforesting was profitable (i.e. for at least one product, $PPx_l \geq 1$). Alternatively, use literature studies, surveys, and other credible and verifiable sources of information. If Option I is not applicable, use Option 2.

If the main motivation is economic profit, agents not allowed to deforest within the *project area* will only displace *deforestation* outside the *project area* if doing so brings economic benefits to them. Based on this rationale, leakage can only occur on land outside the *project area* where:

- The total cost of establishing and growing crops or cattle and transporting the products to the market is less than the price of the products; and
- The land outside the *project area*, where establishment of crops or pasture could be profitable, is still forest land in the *baseline* case at the end of the project crediting period.

All land area outside the *project area* satisfying the above two conditions shall be included in the leakage belt. To identify this land area the following steps shall be applied:

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

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

   - *S$x* = Average selling price per ton of the main products that would be established in the *project area* in the *baseline* case *Px* (meat, crop type A, crop type B, etc.);
   - SPx_l = Most important selling points (spatial locations) for each main product *Px* near the *project area*;
   - PCx_i = Average in situ production costs per ton of product. Stratify the *reference region* as necessary in *i* strata, as production costs may vary depending on local conditions (soil, technology available to the producer, etc.); and,
   - TC_v = Average transport cost per kilometer for one ton of product transported on different types of land-uses (e.g. pasture, cropland, forest), roads and navigable rivers, using the most typical transport technology available to the producer.

c) Using a GIS, generate for each main product a surface representing the least transport cost of one ton of product to the most important selling points existing near the *project area*.

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

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

27

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

f) The leakage belt is the area where the surface created in the previous step (potential profitability) has a positive value and the land is still forest at the end of the crediting period according to the *baseline* projections.

The above methodology procedure can be summarized as follows:

A land unit (pixel *l*) is inside the leakage belt if:

- The land is still forest land the end of the crediting period.; and
- Potential profitability of at least one product (PPx_l) is positive, where PPx_l is calculated as follows:

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

Where:

PPx_l	Potential profitability of product *Px* at location *l* (pixel with coordinates *lat* and *long*); $/t
S$x	Selling Price of product *Px*; $/t
PCx_i	Average *in situ* Production Costs for one ton of product *Px* in stratum *i*; $/t
TCv	Average Transport Cost per kilometer for one ton of product *X* 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

Notes:

1. If Option I leads to a leakage belt area with boundaries that go beyond the range of the potential mobility of the identified main *deforestation* agent groups, Option I may be combined with Option II.
2. In frontier areas, immigrant *deforestation* agents are often the main *deforestation* agents; therefore, the potential mobility of immigrant *deforestation* agents shall be considered in the analysis.
3. A product may be sold at different locations. However, to reduce transport costs, *deforestation* agents are likely to sell their products at the closes location, unless the selling price is substantially lower than at more distant markets. For the

28

definition of the boundary of the leakage belt area, selling points to be considered shall be those that maximize the return to the *deforestation* agent.

Option II: Mobility analysis

With this option, the potential mobility of *deforestation* agents is assessed using multi-criteria analysis. The following methodology steps shall be applied:

a) Using historical data, expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information list all relevant criteria that facilitate and constrain the mobility of the main *deforestation* agents identified in Step 3.

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

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

d) The landscape configuration and the ecological conditions within the selected leakage belt must be similar to the conditions existing within the *project area*. At least three of the following four criteria must be satisfied:

   v. **Forest/vegetation classes:** The area of forest classes or vegetation types within the leakage belt must be within ± 20% of the areas of the same forest classes or vegetation types expected to be deforested in the *project area* in the *baseline* case.

   vi. **Elevation:** At least 80% of the leakage belt area must be within the elevation range of at least 80% of the area expected to be deforested in the *project area* in the *baseline* case.

   vii. **Slope:** The average slope of at least 80% of the leakage belt area must be within ± 10% of the average slope of at least 80% of the area expected to be deforested in the *project area* in the *baseline* case.

   viii. **Rainfall:** The average annual rainfall of the leakage belt area must be within ± 10% of the average annual rainfall of the *project area*.

1.1.4 Leakage management areas

These are areas outside the project boundary and outside the leakage belt area in which the project proponent intends to implement activities that will reduce the risk of activity displacement leakage. The boundary of such areas must be defined according to existing management plans and other plans related to the proposed REDD *project activity*. Such plans shall be made available to the VCS verifier at the time of validation. The boundary of leakage management area shall be clearly defined using the common projection and GIS software formats used in the project.

29

1.1.5 *Forest*

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

In the *baseline* case, changes in the boundary of forest land will be projected[14], and the *baseline* projections must be reassessed at least every 10 years. In the *project area* and leakage belt, the ex post boundary of forest land will be subject to periodical monitoring, verification and reporting (MRV).

To define the boundary of the *forest*, specify:

- The definition of *forest* that will be used to monitor *deforestation* during the *project term* (see Appendix 1 for criteria to define "*forest*"); and,
- The Minimum Mapping Unit (MMU), which shall be equal to the minimum area threshold used for defining "forest".

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

Areas covered by clouds or shadows and for which no spatially explicit and verifiable information on *forest* cover can be found or collected (using ground-based or other methods) shall be excluded (masked out). This exclusion would be:

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

1.2 Temporal boundaries

Define the following temporal boundaries:

[14] Except in the case that the project proponent decides not to use a spatially explicit *baseline* and the thresholds are met to avoid a spatially explicit *baseline*.

30

1.2.1 Starting date and end date of the *historical reference period*

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

1.2.2 Starting date and end date of the REDD *project activity*

The duration of the REDD *project activity* must be at least 20 years and maximum 100 years. This period of time is called crediting period.

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

The *fixed baseline period* can be up to, but no more than, 10 years.

1.2.4 Duration of the *monitoring periods*

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

1.3 Carbon pools

The six carbon pools listed in Table 3 are eligible in this methodology.

31

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

Carbon pools	Included / TBD[1]/ Excluded	Justification / Explanation of choice
Above-ground	Tree: Included	*Carbon stock* change in this pool is always significant
	Non-tree: TBD	To be included if significantly[2] greater in *the baseline* compared to the project case
Below-ground	TBD	Recommended but not mandatory
Dead wood	TBD	
Harvested wood products	TBD	To be included if significantly[2] greater in *the baseline* compared to the project case.
Litter	TBD	
Soil organic carbon	TBD	Recommended when forests are converted to cropland.

Notes:

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

2) The VCS defines as “significant” those carbon pools and sources that account for more than 5% of the total GHG benefits generated (VCS 2007.1,2008 p.17). To determine significance, the most recent version of the “Tool for testing significance of GHG emissions in A/R CDM project activities” shall be used[15].

- Carbon pools that are expected to show a decrease in carbon stocks in the project scenario compared to the *baseline* case must be included if the exclusion would lead to a significant overestimation of the net anthropogenic GHG emission reductions generated during the fixed *baseline* period.
- Above-ground biomass of trees must always be selected because it is in this pool that the greatest carbon stock change will occur.
- Non-tree biomass must be included if the carbon stock in this pool is likely to be relatively large in the *baseline* compared to the project scenario such as when short-rotation woody crops are commonly planted in the region where the *project area* is located. The significance criterion shall apply.
- Below-ground biomass of trees is recommended, as it usually represents between 15% and 30% of the above-ground biomass.

[15] Available at http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

32

- Harvested wood products must be included if removal of timber is associated with significantly more carbon stored in long-term wood products in the *baseline* case compared to the project scenario. The significance criterion shall apply. When included, the carbon stock projected to accumulate in long-lived wood products in the *baseline* case must be subtracted from the total carbon stock of the forest existing prior to *deforestation*. In the project scenario, the carbon stock must be added.
- In most cases the exclusion of a carbon pool will be conservative, except when the carbon stock in the pool is higher in the *baseline* compared to the project scenario.
- The inclusion of a carbon pool is recommended (but not mandatory) where the pool is likely to represent an important proportion (> 10%) of the total carbon stock change attributable to the *project activity* ("expected magnitude of change").
- For excluded pools, briefly explain why the exclusion is conservative.
- When the exclusion of a carbon pool is not conservative, demonstrate that the exclusion will not lead to a significant overestimation of the net anthropogenic GHG emission reduction. If the exclusion is significant, the pool must be included.
- Carbon pools that are excluded or not significant according to the validated *ex ante* assessment do not need not to be monitored *ex post*.
- In most cases, the same carbon pools shall be considered for all categories of LU/LC change. However, including different carbon pools for different categories of LU/LC change is allowed depending on "significance", "conservativeness" and "expected magnitude of change". For instance, harvested wood products may only be considered in the categories where this pool exists.
- The final selection of carbon pools per category is done in Step 2.3. Within a category of LU/LC-change, the same carbon pools must be selected for the two classes involved. Table 1 in Appendix 2 provides an indication of the level of priority for including different carbon pools depending on the category of LU/LC change.
- If a pool is conservatively excluded at validation, project proponent may in subsequent monitoring and verification periods decide to measure, report and verify the excluded carbon pool provided an applicable VCS-approved methodology is used to carry out the estimations and these are independently verified. Further guidance on the selection of carbon pools can be found in the GOFC-GOLD sourcebook for REDD (2009)[16] and further details are given in Appendix 3.

[16] GOFC-GOLD, 2009. 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 GOFC-GOLD Report version COP15-1, (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada).

33

1.4 Sources of GHG emissions[17]

The three sources of GHG emissions listed in Table 4 are eligible in this methodology.

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

Sources	Gas	Included/TBD[1]/ excluded	Justification / Explanation of choice
Biomass burning	CO_2	*Excluded*	Counted as *carbon stock* change
	CH_4	TBD	See guidance below
	N_2O	TBD	See guidance below
Use of fertilizers	CO_2	Excluded	Not a significant source
	CH_4	Excluded	Not a significant source
	N_2O	TBD	See guidance below
Livestock emissions	CO_2	Excluded	Not a significant source
	CH_4	TBD	See guidance below
	N_2O	TBD	See guidance below

Notes:

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

2) The VCS defines as "significant" those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1,2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used[18].

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17 Reducing *deforestation* and *forest degradation* has multiple impacts on sources of GHG emissions (other than carbon stock changes):

- *Baseline emissions are decreased*. Emissions of non-CO_2 gases from forest fires used to convert forests are avoided. Sources of GHG emissions that would be increased on deforested and degraded lands in the absence of the *project activity* are avoided (e.g. fossil fuel consumption due to transport of goods and the services and road construction; fertilization and periodic burning of crop land and grazing land; manure management and enteric fermentation by grazing animals introduced in forested and deforested areas; drainage of deforested peat land forests; flooding of forest areas due to a reservoir construction; etc.); and
- *Project emissions are generated* (e.g. CO_2 emissions due to fossil fuel consumption for project activities such as forest surveillance, improved forest management, carbon monitoring, educational activities, and fire prevention measures); and
- *Leakage emissions are generated* (e.g. non-CO_2 emissions from biomass burning to clear new areas; N_2O emissions from fertilization for agricultural intensification as a *leakage* prevention measure; etc.).

18 Available at http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

34

- Sources of emissions that are expected to show an increase in the project scenario compared to the *baseline* case must be included if the exclusion would lead to a significant overestimation of the total net anthropogenic GHG emission reductions generated during the fixed *baseline* period.
- The inclusion of a source is recommended (but not mandatory) when the source is likely to represent an important proportion (> 10%) of the total emissions reductions attributable to the *project activity* ("expected magnitude of change").
- The exclusion of a source is allowed only if the omission is conservative or the source is insignificant.
- Sources of GHG emissions that are not significant according to the validated *ex ante* assessment do not need not to be monitored *ex post*.
- For excluded sources, briefly explain why the exclusion is conservative.
- In the *baseline* scenario: Non-CO_2 emissions from fires used to clear forests can be counted when sufficient data are available to estimate them. However, accounting for these emissions can conservatively be omitted. GHG emissions, including those from biomass burning and from land-uses implemented on deforested lands 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 fewer emissions of GHG than the *baseline* activities (activities on post *deforestation* land-uses). Therefore, the omission of GHG emissions generated by the REDD *project activity* within the *project area*, such as consumption of fossil fuels, will not cause an overestimation of the net anthropogenic GHG emission reductions. However, if non-CO_2 emissions from fires used to clear forests are counted in the *baseline*, they must also be counted in the project scenario.
- In the estimation of leakage: GHG emissions by sources that are attributable to leakage prevention measures[19] and that are larger when compared to pre-existing GHG emissions count as leakage and should be estimated and counted if they are significant. Non-CO_2 emissions from displaced *baseline* activities, which are conservatively omitted in the *baseline*, can be ignored, as in the worst case scenario they would be similar to *baseline* emissions. However, if non-CO_2 emissions from forest fires used to clear forests are counted in the *baseline*, they must also be counted in the estimation of activity displacement leakage.

[19] The methodology assumes that leakage prevention measures could be implemented in areas outside the *project area* and outside the leakage belt area in specifically designed leakage management areas.

35

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

The goal of this step is to collect and analyze spatial data in order to identify current land-use and land-cover conditions and to analyze land-use and land-cover change during the *historical reference period* within the *reference region* and the *project area*. The tasks to be accomplished in step 2 are the following:

2.1 Collection of appropriate data sources;

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

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

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

2.5 Map accuracy assessment;

2.6 Preparation of a methodology annex to the PD.

2.1 Collection of appropriate data sources

Collect the data that will be used to analyze land-use and land-cover change during the *historical reference period* within the *reference region* and the *project area*. It is good practice to do this for at least three points in time, about 3-5 years apart. For still intact *forest* areas, it is sufficient to collect data for a single date, which must be as closest as possible to the present.

As a minimum requirement:

- Collect medium resolution spatial data[20] (30m x 30m resolution or less, such as Landsat or Spot sensor data) covering the past 10-15 years.
- Collect high-resolution data from remotely sensing platforms (< 5 x 5 m pixels) and/or from direct field observations for ground-truth validation of the posterior analysis. Describe the type of data, coordinates and the sampling design used to collect them. As per the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (volume 4) it is *good practice* to complement the remotely sensed data with ground reference (often called ground truth data). Ground reference data can either be collected independently, or be obtained from forest or agricultural inventories. Land uses that are rapidly changing over the estimation period or that have vegetation cover known to be easily misclassified should be more intensively ground-truthed than other areas. This can only be done by using reference data, preferably from actual ground surveys collected independently. High resolution photographs may also be useful[21].

[20] Guidance on the selection of data sources (such as remotely sensed data) can be found in Chapter 3A.2.4 of the IPCC 2006 GL AFOLU and in Brown *et al.* (2007b), Section 3.2.4. Appendix 2 gives an overview of present availability of optical mid-resolution (10-60m) sensors.

[21] Further information at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_03_Ch3_Representation.pdf (page 3.27).

36

- In tabular format (Table 5), provide the information about the data collected.

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

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

Where already interpreted data of adequate spatial and temporal resolution are available, with some caution[22] these can also be considered for posterior analysis.

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

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

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

b) Carbon stocks *per* hectare (tCO_2-e ha^{-1})[23] within each class are approximately homogeneous across the landscape. Carbon stocks must only be estimated for classes inside the *project area* and leakage belt, which will be done in Step 6.

- The following criteria shall be used to define the LU/LC classes: The minimum classes shall be "Forest Land" and "Non-Forest Land".
- "Forest-land" will in most cases include strata (sub-classes) with different carbon stocks. Forest-land must therefore be further stratified in forest classes having different average carbon densities within each class.

[22] Existing maps should be used with caution because they often do not report documentation, error estimates, whether they were of the site or region in question or extracted from a national map, or whether they were obtained by change detection techniques rather than by static map comparison, etc. If data about historical LU/LC and/or LU/LC-change is already available, information about the minimum mapping unit, the methods used to produce these data, and descriptions of the LU/LC classes and/or LU/LC-change categories must be compiled, including how these classes may match with IPCC 2006 GL AFOLU Chapter 3, Section 3.2, p. 3.5 classes and categories.

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

37

- "Non-Forest Land" may be further stratified in strata representing different non-forest classes. IPCC *LU/LC classes* used for national GHG inventories may be used to define such classes (*Forest* Land, Crop Land, Grassland, Wetlands, Settlements, and Other Land). See IPCC 2006 GL AFOLU Chapter 3, Section 3.2, p. 3.5 for a description of these *classes*. However, where appropriate to increase the accuracy of carbon stock estimates, additional or different sub-classes may be defined.
- The description of a LU/LC class must include criteria and thresholds that are relevant for the discrimination of that class from all other classes. Select criteria and thresholds allowing a transparent definition of the boundaries of the LU/LC polygons of each class. Such criteria may include spectral definitions as well as other criteria used in post-processing of image data, such as elevation above sea level, aspect, soil type, distance to roads[24] and existing vegetation maps. Where needed, in the column "description" of Table 6 refer to more detailed descriptions in the Methodological Annex to be prepared in Step 2.6.
- For all forest classes present in the *project area*, specify whether logging for timber, fuel wood collection or charcoal production are happening in the *baseline* case. If different combinations of class and *baseline* activities are present in the *project area*, define different classes for each combination, even if carbon stocks are similar at the project start date.
- If a forest class has predictably growing carbon stocks (i.e. the class is a secondary forest) and the class is located both in the *project area* and leakage belt, two different classes must be defined (see Step 6.1 for explanations).
- List the resulting final *LU/LC classes* in the following table:

Table 6. Land use and land cover *classes*

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

Notes:

1. Note if "decreasing", "constant", "increasing"
2. RR = *Reference Region*, LK = Leakage Belt, PA = *Project area*

[24] Some classes may be defined using indirect criteria (e.g. "Intact old-growth forest" = Forest at more than 500 m from the nearest road; "Degraded forest" = Forest within 500 m from the nearest road). Using a definition of "degraded forest" as in this example, the boundary of the polygon class "degraded forest" would be a function of how the road network develops over time, which implies that such development will have to be monitored.

38

3. LG = Logging, FW = Fuel-wood collection; CP = Charcoal Production (yes/no)
4. Each class shall have a unique identifier (ID_{cl}). The methodology sometimes uses the notation icl (= 1, 2, 3, … *Icl*) to indicate "initial" (pre-*deforestation*) classes, which are all forest classes; and *fcl* (=1, 2, 3, … *Fcl*) to indicate final" (post-*deforestation*) classes. In this table all classes ("initial" and "final") shall be listed.

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

Identify all *LU/LC-change categories* that could occur within the *project area*, leakage belt and leakage management areas during the crediting period in both, the *baseline* and project case. d. This can be done by analyzing a land-use change matrix that combines all *LU/LC* -*classes* previously defined. See Table 3 in Appendix 2 for an example of a potential land-use change matrix.

List the resulting final *LU/LC-change categories* in Table 7.a and 7.b.

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

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

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

ID_{ct}	Name	Trend in Carbon stock[1]	Presence in[2]	Activity in the *baseline* case [3]			Name	Trend in Carbon stock[1]	Presence in[2]	Activity in the project case[3]		
				LG	FW	CP				LG	FW	CP
I1/F1												
I1/F2												
I1/F…												
I2/F1												
I2/F2												
I2/F…												
I…/F1												
I…/F2												
I…/F…												

39

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

Using the data collected in step 2.1, divide the *reference region* and the *project area* in polygons[25] representing the *LU/LC -classes* and *LU/LC-change categories* defined in steps 2.2 and 2.3.

Use existing LU/LC or LU/LC-change maps if the *classes* and *categories* are well described in these maps, so that they can be matched to the *classes* and *categories* defined in step 2.2 and 2.3.

Where already processed data of good quality are unavailable, unprocessed remotely sensed data must be acquired, preprocessed, and analyzed to produce LU/LC maps and LU/LC-change maps. Given the heterogeneity of methods, data sources and software, LU/LC-change detection should be undertaken by trained interpreters.

Typically, the analysis of LU/LC-change is undertaken by performing the following three tasks:

2.4.1 Pre-processing

2.4.2 Interpretation and classification

2.4.3 Post-processing

2.4.1 Pre-processing

Pre-processing of optical data typically includes:

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

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

c) <u>Radiometric corrections</u>[26] (depending on the change-detection technique used) in order to ensure that similar objects have the same spectral response in multi-temporal datasets; and,

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

Apply the guidance of the latest version of the GOFC-GOLD sourcebook on REDD[27] (i.e. Chapter 2 and 3 in the 2009 version) or consult experts and literature for further guidance on pre-processing techniques.

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25 Raster or grid data formats are allowed.

26 According to GOFC-GOLD (2009), paragraph 3341 to 3345 on the page 2-95, the spectral quality should be checked and related correction are mandatory when satellite sensors with low radiometric processing levels are used, for example TM Landsat 5.

27 GOFC-GOLD, 2009. 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

40

Duly record all pre-processing steps for later reporting.

2.4.2 Interpretation and classification

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

(1) 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 the *LU/LC classes*.

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

As several methods are available to derive LU/LC and LU/LC-change maps from multi-temporal data sets, no specific method is prescribed here. As a general guidance:

- Automated classification methods should be preferred because the interpretation is more efficient and repeatable than a visual interpretation.
- Independent interpretation of multi-temporal images should be avoided (but is not forbidden).
- Interpretation is usually more accurate when it focuses on change detection with interdependent assessment of two multi-temporal images together. A technique that may be effective is image segmentation followed by supervised object classification.
- Minimum mapping unit should be equal to the minimum area threshold used for defining "*forest*".
- See the latest version of the GOFC-GOLD sourcebook on REDD (i.e. Chapter 2 and 3 in the 2009 version) 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.

remaining forests, and forestation GOFC-GOLD Report version COP15-1, (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada).

41

2.4.3 Post-processing

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

Current remote sensing technology is unable to discriminate *carbon density* classes. However, some *forest* types (e.g. broadleaved *forest*, coniferous *forests*, mangroves) can be discriminated with high accuracy using remotely sensed data only.

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

- Biophysical criteria (e.g. climate or ecological zone, soil and vegetation type, elevation, rainfall, aspect, etc.)[28];
- Disturbance indicators (e.g. vicinity to roads; concession areas; etc.), and age (in case of plantations and secondary *forests*);
- Land management categories (e.g. protected *forest*, logging concession, indigenous reserve, etc.); and/or
- Other criteria relevant to distinguish *carbon density* classes.

See the latest version of the GOFC-GOLD sourcebook on REDD (i.e. Section 2.2.4 of the 2009 version) and IPCC 2006 GL AFOLU for further guidance on stratification. The criteria finally used should be reported transparently in the PD and referenced to in Table 6. Some iteration between steps 2.2, 2.3, and 2.4.3 may be necessary.

Duly record all post-processing steps for later reporting.

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

a) A *Forest* Cover Benchmark Map for each date analyzed (showing only "*forest*" and "non-*forest*").

b) A Land-Use and Land-Cover Map for each time point in the past depicting the *LU/LC-classes* defined in step 2.2.

c) A Land-Use and Land-Cover Change Map for each sub-period analyzed, depicting the *LU/LC-change categories* defined in step 2.3. Many projects will have some level of no-data areas because of cloud-cover. In this case change rates should be calculated for each time step based only on areas that were not cloud-obscured in either date in question. Then, a maximum possible forest cover map should be made for the most recent year. The historical rate in % should be multiplied by the maximum forest

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

42

cover area at the start of the period to estimate the total area of *deforestation* during the period.

d) A Land-Use and Land-Cover Change Matrix for each sub-period analyzed, derived from the LU/LC-change maps mentioned above, showing *activity data* for each *LU/LC-change category*. These data will be used to project historical *LU/LC-change* into the future. See Appendix 2, Table 4 for an example of a LU/LC change matrix.

2.5 Map accuracy assessment

A verifiable accuracy assessment of the maps produced in the previous step is necessary to produce a credible *baseline*[29].

The accuracy must be estimated on a *class*-by-*class* (LU/LC map) and *category*-by-*category* (LU/LC-change map) basis, respectively. A number of sample points on the map and their corresponding correct classification (as determined by ground-surveys or interpretation of higher resolution data as collected in step 2.1) can be used to create an error matrix with the diagonal showing the proportion of correct classification and the off-diagonal cells showing the relative proportion of misclassification of each *class* or *category* into the other *class* or, respectively, *categories*. Based on the error matrix (also called confusion or contingency matrix), a number of accuracy indices can be derived (see e.g. Congalton, 1991 and Pontius, 2000).

The minimum overall accuracy of the *Forest Cover Benchmark Map* should be greater than 80 %[30].

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

- Consider merging the *class/category* with other *classes/categories*[31]; or
- Exclude from the *Forest* Cover Benchmark 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 Benchmark Map.

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29 See Chapter 5 of IPCC 2003 GPG, Chapter 3A.2.4 of IPPC 2006 Guidelines for AFOLU, and Section 3.2.4 of Sourcebook on REDD (Brown *et al*., 2007b) for guidance on map accuracy assessment.

30 This value was chosen based on a Conglaton (1991) statement in which he affirmed that accuracy higher than 87% is "quite good" (p.3). Moreover, (Czaplewski 2003)shown at table 5-1 (p.3) an estimated user's accuracy at 90%. And concluding, (Conglaton and Green 2009) have defined an 80%-accuracy level (and 75% for deciduous forest) in their studies (p.150 and table 10.6, p. 153).

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

43

- Both commission errors (false detection of a *class/category*, such as "*deforestation*") and omission errors (non-detection of actual *class/category*, such as "*deforestation*") should be estimated and reported.
- If ground-truthing data are not available for time periods in the past, the accuracy can be assessed only at the most recent date, for which ground-truthing data can be collected.

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

2.6 Preparation of a methodology annex to the PD

LU/LC-change analysis is an evolving field and will be performed several times[32] during the *crediting period*. A consistent time-series of LU/LC-change data must emerge from this process.

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

To achieve a consistent time-series, the risk of introducing artifacts from method change must be minimized. For this reason, the detailed methodological procedures used in pre-processing, classification, post classification processing, and accuracy assessment of the remotely sensed data, must be carefully documented in an <u>Annex to the PDD</u>. In particular, the following information must be documented:

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

b) <u>Data classification and post-processing</u>: Definition of the *LU/LC classes* and *LU/LC-change categories*; classification approach and classification algorithms; coordinates and description of the ground reference data collected for training purposes; ancillary data used in the classification, if any; software and software version used to perform

[32] The periodicity of these analyses will depend on the project monitoring plan, the quality of such data and the *deforestation* profile of the *project area*. It is recommended to perform these analyses at least every 5 year and prior to verification events (VCS, 2008).

44

the classification; additional spatial data and analysis used for post-classification analysis, including class subdivisions using non-spectral criteria, if any; etc.

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

Step 3: Analysis of agents, drivers and underlying causes of *deforestation*

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

This analysis is performed through the following four sub-steps[33]:

3.1 Identification of agents of *deforestation*.;

3.2 Identification of *deforestation* drivers.;

3.3 Identification of underlying causes.;

3.4 Analysis of the chain of events and relations between agents, drivers and underlying causes; and

3.5 Conclusion of the analysis of agents and drivers.

3.1 Identification of *deforestation* agents

Identify the main agent groups of *deforestation* (farmers, ranchers, loggers, etc.) and their relative importance (i.e. the amount of historical LU/LC-change that can be attributed to each of them). To do this identification, use existing studies, the maps prepared in step 2, expert-consultations, field-surveys and other verifiable sources of information, as needed.

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

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

For each identified agent group, provide the following information:

a) Name of the main agent group or agent;

[33] See Angelsen and Kaimowitz (1999) and Chomitz *et al*. (2006) for comprehensive analyses of *deforestation* agents and drivers.

45

b) Brief description of the social, economic, cultural and other attributes of the agent group that are relevant to understand the agent´s motivations to deforest;

c) Current and likely future development of the population size of the agent group in the *reference region* and *project area*.

Approaches to estimate the evolution of the agent group populations shall be based on official statistics, published scientific data, and population models from credible and verifiable sources.

3.2 Identification of *deforestation* drivers

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

Two sets of driver variables have to be distinguished:

a) Non-spatial driver variables (to be used in Step 4.1 and 4.3, as appropriate), such as:

- Prices of agricultural products;
- Costs of agricultural inputs;
- Population density;
- Rural wages;
- *Etc*.

b) Spatial variables explaining the location of land-use and land-cover change, also called “predisposing factors” (De Jong *et al*., 2007) (to be used in step 4.2), such as:

- Access to *forests* (such as vicinity to existing or planned roads, railroads, navigable rivers and coastal lines);
- Slope;
- Proximity to markets;
- Proximity to existing or planned industrial facilities (e.g. sawmills, pulp and paper mills, agricultural products processing facilities, etc.);
- Proximity to *forest* edges;
- Proximity to existing or planned settlements;
- Spatial variables indicating availability within the *forest* of land with good ecological conditions to expand agriculture and cattle ranching, such as soil fertility and rainfall;
- Management *category* of the land (e.g. national park, indigenous, indigenous reserve, etc.);
- *Etc*.

46

Some variables can be used to explain both, the quantity and the location of *deforestation* (i.e. road construction or paving, see for instance Soares-Filho *et al.*, 2006).

For each of these two sets of variables:

1) List the 1-5 key driver variables and provide any relevant source of information that provides evidence that the identified variables are a driver for *deforestation*.
2) Briefly describe for each main agent group identified in step 3.1 how the key driver variables have and will most likely impact on each agent group's decision to deforest.
3) For each identified key driver variable provide information about its likely future development, by providing any relevant source of information.
4) For each identified driver variable briefly describe the project measures that will be implemented to address them, if applicable.

3.3 Identification of underlying causes of *deforestation*

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

- Land-use policies and their enforcement;
- Population pressure;
- Poverty and wealth;
- War and other types of conflicts;
- Property regime;
- *Etc*.

1) List the 1-5 key underlying causes and cite any relevant source of information that provides evidence that the identified variables are an underlying cause for *deforestation*.
2) Briefly describe how each key underlying cause determines the key drivers identified in step 3.2 and the decisions of the main agent groups identified in step 3.1.
3) For each identified key underlying cause provide information about its 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, if applicable.

3.4 Analysis of chain of events leading to *deforestation*

Analyze the relations between the main agent groups, key drivers, and underlying causes and explain the sequence of events that typically leads to *deforestation*. Consult local experts,

47

literature and other sources of information as necessary. Briefly summarize the results of this analysis in the PD.

3.5 Conclusion of the analysis of agents and drivers

The analysis of agents, drivers, underlying causes and chain of events must conclude with a statement about whether the available evidence for the most likely future *deforestation* trend within the *reference region* and *project area* is:

- Inconclusive; or
- Conclusive

In the case that the evidence is conclusive, state whether the weight of the available evidence suggests that the future *baseline deforestation* rates will be:

- decreasing;
- about constant; or
- increasing.

For a conservative *baseline* projection, the project proponent shall consider that in all the scenarios the agents and drivers of the *deforestation* activities are realistic, based on published and reliable data, and including other agents which do not cause *deforestation* in the *baseline* scenarios, (e.g. concrete actions and laws avoiding *deforestation*, such as effective surveillance and law enforcement), thus averting an induced argument.

Step 4: Projection of future *deforestation*

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

If a *baseline* has already been defined for a geographic area that includes the *project area* and this *baseline* is applicable according to the criteria specified in Table 2, the existing *baseline* must be used and the methodology continues with Step 5.

4.1 Projection of the quantity of future *deforestation*

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

Where appropriate, the *reference region* can be stratified and different *deforestation* rates be estimated for each stratum[34]. If the *reference region* is stratified, the rationale for the

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

48

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]			
			1	2	…	*T*
ID_i	Name		ha	ha	ha	ha
1						
2						
..						
n						
I_{RR}						

Note:

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

If the national or sub-national government has adopted a VCS or UNFCCC acknowledged *baseline deforestation* rate that is applicable to the *reference region* and/or the *project area*, the allocated rate must be used even if it is not spatially explicit, and no further analysis is required[35] under this sub-step (continue with step 4.2).

If the above conditions do not exist, future *deforestation* must be determined by taking into account the expected changes at the level of agents, drivers and underlying causes of *deforestation* as well as the remaining forest area that is potentially available for conversion to non-forest uses. This task is performed through the following three sub-steps:

4.1.1 Selection of the *baseline* approach

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

4.1.3 Quantitative projection of future *deforestation*.

4.1.1 Selection of the *baseline* approach

To project future *deforestation* three *baseline* approaches are available:

a) Historical average approach: The rate of *baseline deforestation* is assumed to be a continuation of the average annual rate measured during the historical reference period within the *reference region* or, where appropriate, within different strata of the

[35] Evidence must be provided that a quantitative *deforestation baseline* has been allocated to the *project area* by a competent authority. If such a *baseline* has been allocated to the *project area* but not to the *reference region*, continue with 4.1.1 for the *reference region* only.

49

reference region. In the case of inconclusive evidence in step 3, a discount factor will be used to allow conservative estimates.

b) Time function approach: The rate of *baseline deforestation* will be estimated by extrapolating the historical trend observed within the *reference region* (or its strata) as a function of time using either linear regression, logistic regression or any other statistically sound regression technique (see Step 4.1.3).

c) Modeling approach: The rate of *baseline deforestation* will be estimated using a model that expresses *deforestation* as a function of spatial or non-spatial driver variables selected by the project proponents.

Select and justify the most appropriate *baseline* approach following the decision criteria described below:

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

   1.1 No conclusive evidence emerges from the analysis of agents and drivers explaining the different historical *deforestation* rates: use approach "a"."

   1.2 Conclusive evidence emerges from the analysis of agents and drivers explaining the different historical *deforestation* rates: use approach "c".

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

   2.1 A decrease of the *deforestation* rate and:

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend and making it plausible that this trend will continue in the future: use approach "b".
   - Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend but this evidence also suggest that the decreasing trend will change in the future due to predictable changes at the level of agents and drivers: use approach "c".
   - No conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend: use approach "a".

   2.2 A constant *deforestation* rate and:

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

50

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

- No conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend: use approach “a”.

2.3 An increase of the *deforestation* rate and:

- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend and making it plausible that this trend will continue in the future: use approach “b”. If the future *deforestation* trend is likely to be higher than predicted with approach “b”, use approach “c”.
- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend but this evidence also suggests that the future trend will change: use approach “a” or develop a model (approach “c”).
- No conclusive evidence emerges from the analysis of agents and drivers explaining the increasing trend: use approach “a”.

4.1.2 Analysis of constraints to the further expansion of the *deforestation* frontier

This step only applies if the conclusion of Step 3, which is based on socio-economic criteria, is that the rate of *baseline deforestation* is likely to be “constant” or “increasing” in the whole *reference region* or in some of its strata. If the conclusion was “decreasing” continue with step 5.

A continuation or increase of *deforestation* compared to past trends can only be justified if there are no biophysical constraints to the further expansion of the *deforestation* frontier. To assess whether there are constraints or scarcity of *forest* land that is suitable for conversion to non-*forest* uses do the following:

1) Identify land-use constraints: Identify the biophysical constraints (soil, climate, elevation, slope, etc. – as appropriate) that limit the geographical area where *deforestation* agents could expand their land-use activities in currently forested areas. Consider the constraints as they are expected to exist at the end of the *project term* (e.g. taking into account future road construction) and as they are perceived by the main groups of *deforestation* agents. Prepare maps representing these constraints in order to allow spatial analysis using a GIS.
2) Estimate the remaining *forest* area that could be converted to non-*forest* use: Using the constraints identified above in a GIS, map the area currently covered by *forests* that is potentially suitable for the further expansion of non-*forest* uses in the *reference region*[36] (Maximum Potential *Deforestation* Map). Where the area that is suitable for conversion to non-*forest* uses is more than 100 times the average area

[36] Including the *project area.*

51

annually deforested within the *reference region* during the *historical reference period*, conclude that there is no constraint to the further expansion of the *deforestation* frontier and continue with step 4.1.3; otherwise continue with (3) below.

3) Stratify the "Maximum Potential *Deforestation* Map" in broad suitability classes: Considering the constraints identified above, define criteria and thresholds that delineate "optimal", "sub-optimal" and "marginal"[37] conditions for each of the main land uses implemented by the main *deforestation* agent groups (e.g. by defining ranges of slope, rainfall, types of soils, etc. as appropriate). Select thresholds that are relevant from the point of view of the *deforestation* agents. Using the selected criteria and thresholds stratify the "Maximum Potential *Deforestation* Map" in three broad suitability classes representing "optimal", "average" and "sub-optimal" areas for non-*forest* uses. When available from other sources, use existing maps.

4) Assume that *deforestation* will happen first in "optimal" areas and that in these areas it can continue at the historical or even higher rate. Once "optimal" areas are exhausted, *deforestation* continues in "average" areas but at a lower speed. Finally, *deforestation* must slow down drastically and at the end stop when all "sub-optimal" areas have been cleared.

5) Define future periods that will have different *deforestation* rates:

   - Divide the area of the "optimal" area (ha) by the average area deforested (ha yr^{-1}) in the *reference region* during the *historical reference period* to obtain the number of years where the further expansion of the *deforestation* frontier will not be constrained by insufficient availability of suitable land. During this first period of time the average annual *deforestation* rate can be set as high (or higher) as the average of the *historical reference period*. Where, a higher future *deforestation* rate can be justified (as per step 4.1.2), calculate the number of years of this first period by dividing the "optimal" area by the higher than historical *deforestation* annual area.

   - Once "optimal" areas have become exhausted, *deforestation* is likely to decline because only "average" and "sub-optimal" areas would remain available. Economic returns from activities implemented in "average" areas may not be sufficient for all *deforestation* agents to continue with their traditional activities. For this second period, the *deforestation* rate should be set lower than the average of the *historical reference period*. If the first period is shorter than the *crediting period* calculate the duration of the second period by dividing the area of the "average" area by an estimated and reduced average annual *deforestation* area of the second period.

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

52

- Once “average” areas are exhausted, *deforestation* should decline drastically. If the duration of the first and second period is shorter than the *crediting period*, assume a drastically reduced *deforestation* rate and calculate the number of years needed to exhaust all “sub-optimal” areas. After this third period, no more *deforestation* can happen.

4.1.3 Quantitative projection of future *deforestation*

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

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

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

Approach “a”: Historical average

The historical average *baseline deforestation* area that applies at year t to stratum i within the *reference region* during the first $Toptimal_i$ years is calculated as follows:

$$ABSLRR_{i,t} = ARRhrp_i / Thrp - DFRR_i \qquad (2)$$

Where:

$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum *i* within the *reference region* at a year *t*; ha yr^{-1} Note: The *reference region* may contain just one stratum.
$ARRhrp_i$	Total area deforested during the historical reference period in the *reference region*; ha
Thrp	Duration of the historical reference period in years; yr
$DFRR_i$	Discount factor applicable to stratum *i*; ha yr^{-1} $DFRR_i$ = 0 in case of conclusive evidence about future trends of *deforestation* according to Step 3.5;

- $DFRR_i$ = 50% of the 90% confidence interval of the mean area deforested annually in stratum *i* during the historical reference period in case of inconclusive evidence about future trends of *deforestation* according to Step 3.5. If $ABSLRR_{i,t}$ calculated with this discount factor is lower than

53

the lowest annual historical *deforestation* area, $ABSLRR_{i,t}$ shall be set equal to the lowest annual *deforestation* area.

t	= 1, 2, 3 … T, a year of the proposed crediting period
i	= 1, 2, 3 … I_{RR}, Aa stratum within the *reference region*; dimensionless

The number of years ($Toptimal_i$) during which the value of $ABSLRR_{,i,t}$ calculated with equation 2 is applicable in stratum i is determined as follows:

$$Toptimal_i = Aoptimal_i \ / ABSLRR_{,i,t} \quad (3)$$

Where:

$Toptimal_i$	Number of years since the start of the REDD *project activity* in which *Aoptimal* in stratum i is deforested in the *baseline* case; yr
$Aoptimal_i$	Area of "optimal" *forest land suitable for conversion to non-forest land within stratum* i; ha
$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum i within the *reference region* at a year t; ha yr^{-1}
t	1, 2, 3 … T, a year of the proposed crediting period
i	1, 2, 3 … I_{RR}, a stratum within the *reference region*; dimensionless

If: *Toptimal* $\geq$ Crediting period: $ABSLRR_{,i,t}$ is applicable during the entire crediting period.

If: $Toptimal_i$ < Crediting period: $ABSLRR_{,i,t}$ calculated with equation 2 is applicable only to the first $Toptimal_i$ years. For the following $Taverage_i$ years use $ABSLRR_{,i,t}$ = * 0.5

$Taverage_i$ is calculated as follows:

$$Taverage_i = Aaverage_i / (ABSLRR_{,i,t} * 0.5) \quad (4)$$

Where:

$Taverage_i$	Number of years in which $Aaverage_i$ is deforested in the *baseline* case; yr
$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum i; ha
$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum i within the *reference region* at a year t; ha yr^{-1}
t	1, 2, 3 … T, a year of the proposed crediting period
i	1, 2, 3 … I_{RR}, a stratum within the *reference region*; dimensionless

54

If: $Toptimal_i + Taverage_i \geq$ Crediting period: After $Toptimal_i$ years since the start of the REDD *project activity* and until the end of the crediting period the annual area deforested in stratum i will be $ABSLRR_{,i,t} * 0.5$.

If: $Toptimal_i + Taverage_i < Crediting\ period$: For $Taverage_i$ years after $Toptimal_i$ years since the start of the REDD *project activity* the annual area deforested is stratum i will be $ABSLRR_{,i,t} * 0.5$; after this period, it must be set to $ABSLRR_{,i,t} * 0.25$ for a period of $Tsub\text{-}optimal_i$ years. Finally, after $Toptimal_i + Taverage_i + Tsub\text{-}optimal_i$ it must be set to zero.

$Tsub\text{-}optimal_i$ is calculated as follows:

$$Tsub\text{-}optimal_i = Asub\text{-}optimal_i / (ABSLRR_{,i,t} * 0.25) \quad (5)$$

Where:

$Tsub\text{-}optimal_i$	Number of years in which $Asub\text{-}optimal_i$ is deforested in the *baseline* case; yr
$Asub\text{-}optimal_i$	Area of "sub-optimal" forest land suitable for conversion to non-forest land within stratum i; ha
$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum i within the *reference region* at a year t; ha yr^{-1}
t	1, 2, 3 … T, a year of the proposed crediting period
i	1, 2, 3 … I_{RR}, a stratum within the *reference region*; dimensionless

Approach "b": Time function

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

- Linear regression: $ABSLRR_{,i,t} = a + b*t$ (6.a)
- Logistic regression: $ABSLRR_{,i,t} = ARR_i / (1+e^{-t})$ (6.b)

Where:

$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum i within the *reference region* at a year t; ha yr^{-1}
a	Estimated intercept of the regression line; ha
b	Estimated coefficient of the time variable (or slope of the linear regression); ha yr^{-1}
e	Estimated parameter of the logistic regression

55

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

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

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

The model must be statistically significant at a $p<0.05$ and have an adjusted $r^2 \geq 0.75$. If this cannot be achieved, approaches "a" or "c" shall be used.

When using equation 6.a (or any other model allowing an increase of the $ABSLRR_{,i,t}$ as a function of time) $Toptimal_i$ must be calculated.

If: $b < 0$ → $Toptimal_i$ is the period of time during which equation 6a yields a positive value. After that period of time, $ABSLRR_{,i,t} = 0$.

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

$$Aoptimal_i = \sum_{t=1}^{toptimal_i} ABSLRR_{i,t} \quad (7)$$

Where:

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

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

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

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

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

If: $Toptimal_i \geq$ Crediting period: $ABSLRR_{,i,t}$ calculated with equation 6.a is applicable during the entire crediting period.

If: $Toptimal_i <$ Crediting period: $ABSLRR_{,i,t}$ calculated with equation 6.a is applicable only to the first $Toptimal_i$ years. For the following $Taverage_i$ years use the following equation:

$$ABSLRR_{,i,t} = a + b * toptimal_i \quad (8)$$

Where:

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

a Estimated intercept of the regression line; ha

56

b	Estimated coefficient of the time variable; ha yr^{-1}
t	1, 2, 3 … T, a year of the proposed crediting period
i	1, 2, 3 … I_{RR}, a stratum within the *reference region*; dimensionless
$toptimal_i$	Year at which $Toptimal_i$ ends; yr

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

$$Aaverage_i = \sum_{t=toptimal_i}^{taverage_i} ABSLRR_{i,t} \quad (9)$$

Where:

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

If: $Toptimal_i + Taverage_i \geq$ Crediting period: $ABSLRR_{,i,t}$ calculated with equation 8 is applicable during the period of time between $t = toptimal_i$ and $t = taverage_i$.

If: $Toptimal_i + Taverage_i <$ Crediting period: $ABSLRR_{,i,t}$ calculated with equation 8 is applicable only to the first $Taverage_i$ years following after year $toptimal_i$. For the following years use the following equation:

$$ABSLRR_{,i,t} = a - b * t \quad (10)$$

Where:

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

57

Note: If $ABSLRR_{,i,t} = a - b * t$ calculated with equation 10 is < 0, use $ABSLRR_{,i,t} = 0$.

Approach "c": Modeling

The annual area of *baseline deforestation* that applies at year *t* in stratum *i* within the *reference region* is estimated using a statistical model, such as simple regression, multiple regression, logistic regression, or any other possible model to be proposed and justified by the project proponent. The following equations are given for illustration purposes only:

$$ABSLRR_{,i,t} = a + b1_i * V1_{i,t} \quad (11.a)$$

$$ABSLRR_{,i,t} = a + b1_i * V1_{i,t} + b2_i * V2_{i,t} \quad (11.b)$$

$$ABSLRR_{i,t} = ARR_i / (1 + e^{-V1_{i,t}}) \quad (11.c)$$

Where:

$ABSLRR_{,i,t}$	Annual area of *baseline deforestation* in stratum *i* within the *reference region* at a year *t*; ha yr^{-1}
$a; b1_i; b2_i; ... ; bn_i$	Estimated coefficients of the model
e	Euler's number equals (approximately 2.7183); dimensionless
$V1_{i,t}; V2_{i,t}; ...; Vn_{i,t}$	Variables included in the model
ARR_i	Total forest area in stratum *i* within the *reference region* at the project start date; ha
t	1, 2, 3 … *T*, a year of the proposed crediting period
i	1, 2, 3 … I_{RR}, a stratum within the *reference region*; dimensionless

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

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

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

58

Step 3. The results of the analysis must produce a statistically significant model with a $p \leq \leq 0.05$ and an adjusted r^2 of ≥ 0.50. Seek assistance from an expert statistician as necessary.

4.1.3.2 Projection of the annual areas of *baseline deforestation* in the *project area*

In case of project activities avoiding frontier *deforestation* spatial analysis is required to determine the annual areas of *baseline deforestation* in the *project area* (Step 4.2). Once location analysis is completed, the portions of annual areas of *baseline deforestation* within each stratum *i* that are within the *project area* must be determined using a GIS.

4.1.3.3 Summary of step 4.1.3

Present the result of the previous assessments in Table 9.a and 9.b. At a minimum, do this for the fixed *baseline* period or, optionally, for the entire crediting period.

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

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

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

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

59

If certain leakage prevention activities involve planned *deforestation* in leakage management areas, do the same for the leakage management area and present the results in Table 9.c.

Table 9.c Annual areas of *baseline deforestation* in leakage management areas

Project year	Stratum *i* of the *reference region* in the *project area*				Total	
	1	2	…	I_{RR}	annual	cumulative
	$ABSLLM_{i,t}$	$ABSLLM_{i,t}$	$ABSLLM_{i,t}$	$ABSLLM_{i,t}$	$ABSLLM_t$	$ABSLLM$
	ha	ha	ha	ha	ha	ha
1						
2						
. . .						
T						

4.2 Projection of the location of future *deforestation*

Step 4.1 was to estimate annual areas of *baseline deforestation*. Step 4.2 is to analyze *where* future *deforestation* is most likely to happen in the *baseline* case; this is in order to match location of *deforestation* with *carbon stocks* and determine both the annual areas of *baseline deforestation* in the *project area* and locations where planned *deforestation* will occur in leakage management areas. Step 4.2 is based on the assumption that *deforestation* is not a random event but a phenomenon that occurs at locations that have a combination of bio-geophysical and economic attributes that is particularly attractive to the agents of *deforestation*. For example, a *forest* located on fertile soil, flat land, and near to roads and markets for agricultural commodities is at greater risk of *deforestation* than a *forest* located on poor soil, steep slope, and far from roads and markets. Locations at higher risk are assumed to be deforested first. This hypothesis can be tested empirically by analyzing the spatial correlation between areas deforested in the past and geo-referenced biogeophysical 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 *et al*., 2007). These variables can be represented in a map (or "Factor Map") and overlaid on a map showing historical *deforestation* using a Geographical Information System (GIS). From the combined spatial dataset, information is extracted and analyzed statistically in order to produce a raster 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 parameters of the Factor Maps changes their values due to projected changes. For example, when a new road is constructed, the variable "distance to road" will have smaller values and the risk of *deforestation* will increase.

60

The basic tasks to perform the analysis described above are:

4.2.1 Preparation of factor maps;

4.2.2 Preparation of *deforestation* risk maps;

4.2.3 Selection of the most accurate *deforestation* risk map;

4.2.4 Mapping of the locations of future *deforestation*.

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

4.2.1 Preparation of factor maps

Based on the analysis of Step 3 and Step 4.1, identify the spatial variables that most likely explain the patterns of *baseline deforestation* in the *reference region*. Obtain spatial data for each variable (i.e. the shape files representing the point, lines or polygon features or the raster files representing surface features). Some models, such as GEOMOD, will often require producing Distance Maps from mapped features (e.g. distance to roads or distance to already deforested lands) or maps representing continuous variables (e.g. slope classes) and categorical variables (e.g. soil quality classes). If the model/software allows working with dynamic Distance Maps (i.e. the software can calculate a new Distance Maps at each time step), these should be used. For simplicity, these maps are called "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.

If some of the spatial variables are expected to change, collect information on the expected changes from credible and verifiable sources of information, and prepare factor maps representing the changes that may occur in various future periods. Sometimes, projected changes can be modeled and the program code of the model will generate new factor maps for each future year.

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

In case of unplanned infrastructure (e.g. secondary roads), provide evidence that the unplanned infrastructure will actually develop, e.g. from historical developments. Specifically, from at least five examples observed in the *reference region* or from literature sources appropriate to the *reference region*, estimate the length of secondary roads constructed

61

per km of official roads constructed, or the length of secondary roads constructed per industrial facility/settlement, or per square kilometer within a certain type of land use (such as private land, forestry concessions, protected areas) during an historical time period, etc. From the examples the average result shall be applied (i.e. the average number of km per year of secondary roads per km of primary road, or per industrial facility or settlement etc.) for application to the project. Alternatively, determine the historical rate of change as related to variables for which there are good projections (e.g. km of new unplanned roads as related to population). Use these values to bolster evidence in the PD about the development of unplanned infrastructure.

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

- **Heuristic approach**: Define "value functions" representing the likelihood of *deforestation* as a function of distance from point features (e.g. saw mills) or linear features (e.g. roads), or as a function of polygon features representing classes (e.g. of soil type, population density) based on expert opinion[38] or other sources of information. Specify and briefly explain each value function in the PD.

  A useful approach to estimate value functions is to sample spatially uncorrelated points in the Distance Maps and their corresponding location in the Land-Use and Land-Cover Change Maps produced with step 2 and to use regression techniques[39] to define the probability of *deforestation* as a function of "distance".

- **Empirical approach:** Categorize each Distance Map in a number of predefined distance classes (e.g. class 1 = distance between 0 and 50 m; class 2 = distance between 50 and 100 m, etc.). In a table describe the rule used to build the classes and the *deforestation* likelihood assigned to each distance class[40]. The *deforestation* likelihood is estimated as the percentage of pixels that were deforested during the period of analysis (i.e. the *historical reference period*).

[38] An expert may be defined, based on the VCS Program Normative Document (available at http://v-c-s.org/docs/VCS-Program-Normative-Document_Double-Approval-Process_v1.1.pdf), as a person with expertise and experiences in the requested field (e.g., methodologies, techniques, approaches) as well as being well recognized by them. In the context of understanding factors that explain *deforestation* patterns, a person with local knowledge (not necessarily a scientist) or a technical expert (with scientific skills) that can provide useful experience and knowledge about *deforestation* patterns and variables determining them in the *reference region* and *project area* shall be considered an "expert".

[39] e.g. logistic regression.

[40] When building classes of continuous variables it is important to build classes that are meaningful in terms of *deforestation* risk. This implies the parameterization of a "value function" (Malczewski, 1999) based on specific measurements. For instance, the criterion "distance to roads" might not have a linear response to assess the *deforestation* risk: a forest located at 50 km from the nearest road may be subject to the same *deforestation* risk of a forest located at 100 km, while at 0.5 km the risk may be twice as much as at 1.0 km. Data to model the value function and build meaningful classes can be obtained by analyzing the distribution of sample points taken from historically deforested areas.

62

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

4.2.2 Preparation of *deforestation* risk maps

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

Models use different techniques to produce Risk Maps and algorithms may vary among the different modeling tools. Algorithms of internationally peer-reviewed modeling tools are eligible to prepare *deforestation* risk maps provided they are shown to conform with the methodology at time of validation.

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

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

Table 10. List of variables, maps and Factor Maps

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

4.2.3 Selection of the most accurate *deforestation* risk map

Confirming the quality of the model output (generally referred to as "model validation" in the modeling community) is needed to determine which of the *deforestation* risk maps is the most accurate. A good practice to prepare model output (such as a risk map) is "calibration and validation", referred to here as "calibration and confirmation" (so as not to be confused with validation as required by the VCS).

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

63

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

   Using only the data from the calibration period, prepare for each Risk Map a Prediction Map of the *deforestation* for the confirmation period. Overlay the predicted *deforestation* with locations that were actually deforested during the confirmation period. Select the Prediction Map with the best fit and identify the Risk Map that was used to produce it. Prepare the final Risk Map using the data from the calibration and the confirmation period.

b) Where only one historical sub-period is representative of what is likely to happen in the future, divide the *reference region* in tiles and randomly select half of the tiles for the calibration data set and the other half for the validation 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. Several peer-reviewed methods to compare maps and test the goodness-of-fit exist and can be used to identify the map that best reproduced actual *deforestation* (see for instance Hagen, 2002 and 2003[41]). The Research Institute for Knowledge Systems has developed a tool that can be used to calculate several map comparison statistics (RISK 2009)[42]. A simple statistic to assess the best fit is the "Figure of Merit" (FOM) that confirms the model prediction in statistical manner (Pontius *et al*. 2008; Pontius *et al*. 2007)[43].

The FOM is a ratio of the intersection of the observed change (change between the reference maps in time 1 and time 2) and the predicted change (change between the reference map in time 1 and simulated map in time 2) to the union of the observed change and the predicted change (equation 13). The FOM ranges from 0.0, where there is no overlap between observed and predicted change, to 1.0 where there is a perfect overlap between observed and predicted change. The highest percent FOM must be used as the criterion for selecting the most accurate *Deforestation* Risk Map to be used for predicting future *deforestation*.

$$FOM = B / (A+B+C+D) \qquad (13)$$

Where:

[41] Hagen, A., 2002). Technical report: comparison of maps containing nominal data, Research Institute for Knowledge Systems. Hagen, A., 2003. "Fuzzy set approach to assessing similarity of categorical maps." International Journal of Geographical Information Science 17(3): 235-249.

[42] RISK, 2009. Map comparison kit 3 user manual, Research Institute for Knowledge Systems. http://www.riks.nl/products/Map_Comparison_Kit.

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

64

FOM “Figure of Merit”; dimensionless

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

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

C Area of error due to observed change predicted as wrong gaining category; ha

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

4.2.4 Mapping of the locations of future *deforestation*

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

To determine the locations of future *deforestation* do the following:

- In the most accurate *Deforestation* Risk Map, select the pixels with the highest risk value summing total area until this value is equal to the area expected to be deforested in project year one according to Table 9.a. The result is the Map of *Baseline Deforestation* for Year 1.
- Repeat the above pixel selection procedure for each successive project year *t* to produce a Map of *Baseline Deforestation* for each future project year. Do this at least for the upcoming *fixed baseline period* or, optionally, for the entire *crediting period*.
- Add all yearly *baseline deforestation* maps in one single map showing the expected *Baseline Deforestation* for the *fixed baseline period* and, optionally, *crediting period.* Present this map in the PD.

The described pixel selection procedure and production of annual maps of *baseline deforestation* con be programmed in most state of the art modeling-software.

To obtain the annual areas of *baseline deforestation* within the *project area*, the annual maps of *baseline deforestation* for the *reference region* must be overlaid with a map layer corresponding only to the *project area*. After this step, Table 9.b can be filled-out.

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

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

Two methods can be used to achieve this objective:

Method 1: For each future year the area and location (polygons) that would be deforested in the *baseline* case is determined for each *forest class*. In case of the non-*forest classes* that replace the *forest* after a *deforestation* event only the area, but not the location, is identified.

65

Method 2: The annual areas and locations are determined for both, the pre-*deforestation forest classes* and the post-*deforestation* non-*forest classes*.

When using method 1, complete step 5.1 and 5.2. When using method 2, also complete step 5.3.

5.1 Calculation of *baseline* activity data per pre-*deforestation forest class*;

5.2 Calculation of *baseline* activity data per post-*deforestation* non-*forest classes*; and

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

5.1 Calculation of *baseline* activity data per *forest class*

Combine the <u>Maps of *Baseline Deforestation*</u> of each future year *t* produced in the previous step with the <u>Land-Use and Land-Cover Map</u> produced for the current situation in step 2 to produce a set of maps showing for each *forest class* the polygons that would be deforested each year (in the absence of the REDD *project activity*). Extract from these maps the number of hectares of each *forest class* that would be deforested and present the results in Table 11. At a minimum, do this for the fixed *baseline* period or, optionally, for the project crediting period.

Table 11: Annual areas deforested per forest class *icl*[44] within the *project area* in the *baseline* case (*baseline* activity data per forest class)

Area deforested per forest class **fcl***icl* within the *project area*					Total *baseline deforestation* in the *project area*	
icl	1	2	…	*Icl*		
Name >					$ABSLPA_t$ annual	*ABSLPA* cumulative
Project year v	ha	ha	ha	ha	ha	ha
1						
2						
3						
. . .						
T						

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

Three options are available to project the *LU/LC classes* that will replace *forests* in the *baseline* case: (1) "Simple conservative approach"; (2) "Historical LU/LC-change" and (3)

44 *icl* = "initial class"; *fcl* "final class"

66

"Modeling". All three options can be used in conjunction with method 1, but option 3 should be the preferred one under method 2.

Option 1: Simple conservative approach

A conservative average *carbon density* is estimated for all post-*deforestation* land uses. Do the following:

- List the non-*forest classes* in descending order of *carbon density*.
- Select from the top of the list the *classes* that represent 30% of all non-*forest classes* (at least one *class*).
- Calculate the average *carbon density* of the selected *classes*.
- Assume that the calculated average *carbon density* is representative of the post-*deforestation carbon density* on all lands that will be deforested during the project term.

Option 2: Historical LU/LC-change

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

Do the following calculations:

- Using the maps produced in Step 2, calculate the area of each non-*forest class* on lands deforested during the *historical reference period.*
- Calculate the percentage of area of each non-*forest class* relative to the total area deforested during the *historical reference period*.
- Multiply the annual (or periodical) *deforestation* area ($ABSLPA_t$) calculated in Table 9.b by the percentage calculated for each *non-forest-class* and report the result in Table 12.

67

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

Area established after *deforestation* per class f*cl* within the *project area*					Total *baseline deforestation* in the *project area*	
fcl	1	2	…	*Fcl*		
Name >					*$ABSLPA_t$* annual	*ABSLPA* cumulative
Project year v	ha	ha	ha	ha	ha	ha
1						
2						
3						
. . .						
T						

Option 3: Modeling

The future spatial distribution of *non-forest classes* is determined using spatial modeling.

Two modeling techniques can be used:

a) Projection of LU/LC-change categories: Some *deforestation* modeling tools can be used to project several LU/LC-change categories at the same time, instead of just the broad category "*deforestation*". In such cases, the non-forest classes are determined by each projected category of change.

b) Suitability modeling:

- Criteria must be identified to determining the suitability of each main non-forest use, such as soil type, elevation, slope etc. (as selected and justified by the project proponent).
- Using multi-criteria analysis the suitability of each non-forest class is determined for each spatial location. At each spatial location the class with the highest suitability value is assumed to be the one that *deforestation* agents will implement in absence of the REDD *project activity*

Show the results obtained in maps and summarize the results in Table 12 above.

Selection of the most appropriate option:

<u>Option 1</u> is the most simple and conservative approach and can always be used. However, the use of this option can lead to an overly conservative underestimation of the *baseline*, in which case option two or three should be considered.

68

Option 2 is simple where good information on historical land-use and land-cover exists, but it may not be applicable where scarcity of "optimal" and "sub-optimal" land for some of the main land-uses has been detected in step 4.1.2. In this case option three should be used.

Option 3 is more laborious and costly to implement, but it may represent future changes in a more accurate manner than option one or two. It should be used where the different land-uses are already competing for suitable land or where such competition is likely to become a critical factor during the *crediting period* according to the analysis performed in step 4.1.2.

5.3 Calculation of *baseline* activity data per land-use and land-cover change *category*

Do this sub-step only if the method selected for Step 5 is method 2.

The goal of this sub-step is to identify the *categories* of LU/LC-change and the level of *activity data* of each of these *categories*. This is performed as follows:

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

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

c) Extract from the maps produced above the number of hectares (= *activity* data) corresponding to each future year *t*.

d) Summarize the results in Table 13 for the fixed *baseline* period or, optionally, for the entire crediting period

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

Activity data per LU/LC category *ct* within the *project area*					Total *baseline deforestation* in the *project area*	
ct	1	2	…	*CT*		
Name >					$ABSLPA_t$ annual	*ABSLPA* cumulative
Project year v	ha	ha	ha	ha	ha	ha
1						
2						
3						
. . .						
T						

69

Step 6: Estimation of *baseline carbon stock* changes and non-CO_2 emissions

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

6.1 *Baseline carbon stock* changes; and (optionally)

6.2 *Baseline* non-CO_2 emissions from forest fires used to clear forests

6.1 Estimation of *baseline carbon stock* changes

Before calculating the *baseline carbon stock* changes, it is necessary to estimate the average *carbon stock* per hectare (tCO_2-e ha^{-1}, also called *carbon density*) of each *LU/LC class*.

6.1.1 Estimation of the average carbon stocks of each LU/LC class ($Ctot_{cl}$)

Average carbon stocks must be estimated only for:

- the forest classes existing in the *project area* at the project start date;
- the forest classes existing in the leakage belt at the end of the crediting period;
- the non-forest classes projected to exist in the *project area* in the *baseline* case; and
- the non-forest classes projected to exist in the leakage belt in the project case.

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

a) Assess and, where appropriate, use existing data. It is likely that some existing data could be used to quantify the *carbon stocks* of one or more *classes*. These data could be derived from a *forest* inventory or perhaps from scientific studies. Analyze these data if the following criteria are fulfilled (Brown *et al.*, 2007b):

  - The data are less than 10 years old;
  - The data are derived from multiple measurement plots;
  - All species must be included in the inventories;
  - The minimum diameter for trees included is 30 cm or less at breast height (DBH); and,
  - Data are sampled from good coverage of the classes over which they will be extrapolated.

  Existing data that meet the above criteria should be applied across the classes from which they were representatively sampled and not beyond that. See the most recent

70

version of the GOFC-GOLD sourcebook on REDD (2009 at the time of writing) and Gillespie, *et al.* (1992) for methods to analyze these data.

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

Field measurements:

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

Design the sampling framework and conduct the field measurements following the guidance of Appendix 3 (see also Chapter 4.3 of GPG LULUCF and in the Sourcebook for LULUCF by Pearson *et al.*, 2006). Summarize the sampling design in the PD and provide a map and the coordinates of all sampled locations.

Literature estimates:

The use of carbon stock estimates in similar ecosystems derived from local studies, literature and IPCC defaults is permitted, provided the accuracy and conservativeness of the estimates are demonstrated. For instance, when defaults are used, the lowest value of the range given in the literature source (or the value reduced by 30%) should be used for the *forest* classes, and the highest value (or the value augmented by 30%) for non-*forest* classes.

The same conservative principle applies to factors used to convert volume data to above-ground biomass data (biomass expansion factor) or to estimate below-ground biomass (root to shoot ratio) and other non-measured carbon pools.

Carbon stocks of forest-classes in the *project area* are conservatively assumed to have constant carbon stocks in the *baseline* case. If the forest within the *project area* in the *baseline* scenario is degrading and losing carbon stocks, or growing and accumulating carbon stocks, it can safely be assumed that under the project scenario carbon loss will be the same or less, and carbon accumulation the same or more compared to the *baseline* case; this is particularly true if the forest will, at some time point during the crediting period, be deforested in the *baseline* case. If carbon stocks are decreasing more in the project case than in the *baseline* case (e.g. when the *project activity* involves logging for timber, fuel-wood collection or charcoal production in areas not subject to such activities in the *baseline* case), this will have to be accounted in the project case. If logging activities are present in the *baseline*, the harvested wood product carbon pool must be estimated, and – if significantly higher in the *baseline* compared to the project scenario – it will also have to be accounted and monitored.

Carbon stocks of forest-classes in the leakage belt cannot always be assumed to have constant carbon stocks in the *baseline*. The following three cases must be distinguished:

71

<u>Degrading forest</u>: The carbon stock existing at the project start date can conservatively be assumed to persist until the end of the fixed *baseline* period, even if it is likely to decrease due to *baseline* activities such as logging, fuel-wood collection or charcoal production. If the forest will be deforested or degraded more in the project scenario than in the *baseline* case as a consequence of activity displacement leakage, emissions will be less than calculated with the constant carbon stock assumption, which is conservative. If the project proponent considers that degradation of forests in the leakage belt in the *baseline* case is significant, an applicable VCS approved IFM methodology shall be used to estimate the *baseline* carbon stock decrease.

<u>Mature forest</u>: The carbon stock existing at the project start date may not change significantly during the fixed *baseline* period. If activity displacement leakage occurs, emissions will be about similar to the ones calculated with the constant carbon stock assumption.

<u>Secondary (growing forest)</u>: If a forest not projected to be deforested in the *baseline* case[45] is growing, and – due to activity displacement leakage it will be deforested or degraded – then emissions will be higher than calculated with a constant carbon stock assumption, which is not conservative. For this reason, carbon stocks of secondary (growing) forests located within the leakage belt must be estimated as the projected carbon stock existing at the end of the fixed *baseline* period. At that point in time, the carbon stock will have to be reassessed. To do the projection, use credible and verifiable sources of data from existing studies, or measure field plots in secondary forests of different known age.

Carbon stocks of post-*deforestation* classes (non-forest classes) often do not have a stable carbon stock because different land uses may be implemented in a time sequence or because the land use established after *deforestation* implies carbon stocks changed over time (e.g. in case of tree plantations)[46]. The carbon stock of post-*deforestation* classes must be estimated as the long-term (20 years) average carbon stock and can be determined from measurements in plots of known age, long-term studies and other verifiable sources.

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

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[45] The leakage belt shall include only forests not expected to be deforested during the crediting period.

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

72

Table 14. Average carbon stock per hectare of all land use and land cover classes present in the leakage belt and *project area*

LU/LC class		Average carbon stock per hectare ± 90% CI													
		Cab_{cl}		Cbb_{cl}		Cdw_{cl}		Cl_{cl}		$Csoc_{cl}$		Cwp_{cl}		$Ctot_{cl}$	
		average stock	± 90% CI	*average stock*	± 90% CI	*average stock*	± 90% CI	*average stock*	± 90% CI	*average stock*	± 90% CI	*average stock*	± 90% CI	*average stock*	± 90% CI
ID_{cl}	Name	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}
1															
2															
...															
Ncl															

Cab_{cl} Average carbon stock per hectare in the above-ground biomass carbon pool of class *cl*; $tCO_2e\ ha^{-1}$

Cbb_{cl} Average carbon stock per hectare in the below-ground biomass carbon pool of class *cl*; $tCO_2e\ ha^{-1}$

Cdw_{cl} Average carbon stock per hectare in the dead wood biomass carbon pool of class *cl*; $tCO_2e\ ha^{-1}$

Cl_{cl} Average carbon stock per hectare in the litter carbon pool of class *cl*; $tCO_2e\ ha^{-1}$

$Csoc_{cl}$ Average carbon stock in the soil organic carbon pool of class *cl*; $tCO_2e\ ha^{-1}$

Cwp_{cl} Average carbon stock per hectare accumulated in the harvested wood products carbon pool between project start and the year of *deforestation* (stock remaining in wood products after 100 years) of class *cl*; $tCO_2e\ ha^{-1}$

$Ctot_{cl}$ Average carbon stock per hectare n all accounted carbon pools cl; tCO2e ha-1

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

$Ctot_{cl}$ Average carbon stock per hectare n all accounted carbon pools *cl*; $tCO_2e\ ha^{-1}$

6.1.2 Calculation of *baseline carbon stock* changes

Carbon stock changes are calculated differently, depending on whether activity data are available for classes or for categories.

- If 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:

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

Where:

$\Delta CBSLPA_t$	Total *baseline carbon stock* change within the *project area* at year t; tCO_2etCO_2-e
$ABSLPA_{icl,t}$	Area of initial forest class *icl* deforested at time *t* within the *project area* in the *baseline* case; ha
$Ctot_{icl,t}$	Average carbon stock of all accounted carbon pools in the initial forest class *icl* at time *t*; tCO_2etCO_2-e
$ABSLPA_{fcl,t}$	Area of the final non-forest class *fcl* deforested at time *t* within the *project area* in the *baseline* case; ha
$Ctot_{fcl,t}$	Average carbon stock of all accounted carbon pools in non-forest class *fcl* at time *t*; tCO_2etCO_2-e
icl	= 1, 2, 3 … *icl*, … *Icl* initial (pre-*deforestation*) forest classes
fcl	= 1, 2, 3 … *fcl*, … *Fcl* final (post-*deforestation*) non-forest classes
t	= 1, 2, 3 … *T* a year of the proposed crediting period

<u>Note:</u> Carbon stocks are assumed not to change within a fixed *baseline* period

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

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

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

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

Project year	Carbon stock changes in final (post-*deforestation*) non-forest classes								Total C stock change in final non-forest classes	
	ID_{fcl} = 1		ID_{fcl} = 2		ID_{fcl} = . . .		ID_{fcl} = *Fcl*		annual	cumulative
	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$ABSLPA_{fcl,t}$	$Ctot_{fcl,t}$	$\Delta CBSLPAf_t$	$\Delta CBSLPAf$
	ha	$tCO_2e$$tCO_2$-e ha^{-1}	ha	$tCO_2e$$tCO_2$-e ha^{-1}	ha	$tCO_2e$$tCO_2$-e ha^{-1}	ha	$tCO_2e$$tCO_2$-e ha^{-1}	tCO_2e tCO_2-e	tCO_2e tCO_2-e
1										
2										
. . .										
T										

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

Project year	Total C stock change in initial forest classes		Total C stock change in final non-forest classes		Total *baseline* carbon stock change	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLPAi_t$	$\Delta CBSLPAi$	$\Delta CBSLPAf_t$	$\Delta CBSLPAf$	$\Delta CBSLPA_t$	$\Delta CBSLPA$
	tCO_2e tCO_2-e	tCO_2e tCO_2-e	tCO_2e tCO_2-e	tCO_2e tCO_2-e	tCO_2e tCO_2-e	tCO_2e tCO_2-e
1						
2						
. . .						
T						

75

- If activity data are available for categories (Method 2), first calculate the carbon stock change factor ($\Delta Ctot_{ct,t}$)[47] of each category (also called "emission factor"), then calculate the total *baseline* carbon stock change in the *project area* at year *t* as follows:

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

Where:

$\Delta CBSLPA_t$	Total *baseline* carbon stock change within the *project area* at year *t*; tCO_2-e
$ABSLPA_{ct,t}$	Area of category *ct* deforested at time *t* within the *project area* in the *baseline* case; ha
$\Delta ctot_{ct}$	Carbon stock change factor (also called emission factor) for all accounted carbon pools in category *ct* at time *t*; tCO_2-e ha^{-1}
ct	= 1, 2, 3 … *ct categories* of LU/LC change
t	= 1, 2, 3 … *t* a year of the proposed crediting period
	Note: Carbon stock change factors are assumed not to change within a *fixed baseline period*
ct	1, 2, 3, … *CT* categories of LU/LC change
t	1, 2, 3, … *T* a year of the proposed *crediting period*

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

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

76

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

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

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

Project year	Activity data per category x Carbon stock change factor								Total baseline carbon stock change	
	ID_{ct} = 1		ID_{ct} = 2		ID_{ct} = . . .		ID_{ct} = Ict		annual	cumulative
	$ABSLPA_{ct,t}$	$\Delta Ctot_{ct,t}$	$ABSLPAct,t$	$\Delta Ctot_{ct,t}$	$ABSLPAct,t$	$\Delta Ctot_{ct,t}$	$ABSLPAct,t$	$\Delta Ctot_{ct,t}$	$\Delta CBSLPA_t$	$\Delta CBSLPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

6.2 Estimation of non-CO_2 emissions from *forest* fires

Emissions from fire used to clear forests in the *baseline* can always be conservatively be omitted.

Conversion of *forest* to non-*forest* involving fires is a source of emissions of non-CO_2 gases (CH_4 and N_2O). When sufficient data on such *forest* fires are available from the *historical reference period* and the project proponent considers that these emissions are an important component of the *baseline*, emissions of non-CO_2 gases from biomass burning can be estimated. Where such data are unavailable, or of insufficient accuracy, emissions from biomass burning should not be considered (which is conservative). Where applicable to the local conditions, emissions data from peer reviewed studies or other credible and verifiable sources can also be used.

The effect of fire on carbon emissions is counted in the estimation of *carbon stock* changes; therefore CO_2 emissions from *forest* fires should be ignored to avoid double counting.

To estimate non-CO_2 emissions from *forest* fires, it is necessary to estimate the average percentage of the deforested area in which fire was used, the average proportion of mass burnt in each carbon pool ($P_{burned,p}$), and the average combustion efficiency of each pool (CE_p). These average percentage values are estimated for each *forest class* and are assumed to remain the same in the future.

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

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

Where:

$EBBtot_{icl,t}$ Total GHG emission from biomass burning in forest class *icl* at year *t*; tCO_2e

$EBBN2O_{icl,t}$	N_2O emission from biomass burning in forest class *icl* at year *t*; tCO_2e
$EBBCH4_{icl,t}$	CH_4 emission from biomass burning in forest class *icl* at year *t*; tCO_2e

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

$$EBBnCH4_{icl,t} = EBBCO2_{icl,t} * 12/44 * ER_{CH4} * 16/12 * GWP_{CH4} \quad (18)$$

Where[48]:

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class *icl* at year *t*; $tCO_2e\ ha^{-1}$
$EBBN2O_{icl,t}$	Per hectare N_2O emission from biomass burning in slash and burn in forest class *icl* at year *t*; $tCO_2e\ ha^{-1}$
$EBBCH4_{icl,t}$	Per hectare CH_4 emission from biomass burning in slash and burn in forest class *icl* at year *t*; $tCO_2e\ ha^{-1}$
NCR	Nitrogen to Carbon Ratio (IPCC default value = 0.01); dimensionless
ER_{N2O}	Emission ratio for N_2O (IPCC default value = 0.007)
ER_{CH4}	Emission ratio for CH_4 (IPCC default value = 0.012)
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)); dimensionless
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period); dimensionless

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

Where:

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in the forest class *icl* at year *t*; $tCO_2e\ ha^{-1}$
$Fburnt_{icl}$	Proportion of forest area burned during the historical reference period in the forest class *icl*; %
$C_{p,icl,t}$	Average *carbon stock* per hectare in the carbon pool *p* burnt in the forest class *icl* at year *t*; $tCO_2e\ ha^{-1}$
$Pburnt_{p,icl}$	Average proportion of mass burnt in the carbon pool *p* in the forest class *icl*; %

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

79

$CE_{,p,icl}$	Average combustion efficiency of the carbon pool *p* in the forest class *icl*; dimensionless
p	Carbon pool that could burn (above-ground biomass, dead wood, litter)
icl	1, 2, 3, … *icl* (pre-*deforestation*) *forest classes*

The combustion efficiencies may be chosen from Table 3.A.1.14 of IPCC GPG LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used. The Nitrogen/Carbon ratio (N/C ratio) is approximately 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if these data are available. Emission factors for use with equations above are provided in Tables 3.A.1.15 and 3.A.1.16 of IPCC GPG LULUCF.

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

Table 18. Parameters used to calculate non-CO_2 emissions from forest fires

Initial Forest Class		**Parameters**																
		$Fburnt_{icl}$	*Cab*	*Cdw*	*Cl*	*$Pburnt_{ab,icl}$*	*$Pburnt_{dw,icl}$*	*$Pburnt_{l,icl}$*	*$CE_{ab,icl}$*	*$CE_{dw,icl}$*	*$CE_{l,icl}$*	*ECO2-ab*	*ECO2-dw*	*ECO2-l*	*EBBCO2-tot*	*$EBBnN2O_{icl}$*	*$EBBCH4_{icl}$*	*$EBBtot_{icl}$*
IDcl	Name	%	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	%	%	%	%	%	%	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$
1																		
2																		
. . .																		
Icl																		

80

Finally, using the parameters specified in Table 18 and the projected activity data for forest classes calculate the projected total non-CO_2 emissions from *forest* fires and report the results in Table 19.

Table 19. *Baseline* non-CO_2 emissions from forest fires in the *project area*

Project year	Emissions of non-CO_2 gasses from *baseline* forest fires								Total *baseline* non-CO_2 emissions from forest fires in the *project area*	
	ID_{icl} = 1		ID_{icl} = 2		ID_{icl} = . . .		ID_{icl} = Icl		annual	cumulative
	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$EBBBSLPA_t$	$EBBBSLPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

6.3 Total *baseline* carbon stock changes and GHG emissions

Summarize the results of all *baseline* estimations in Table 20.

Table 20. Total *baseline* carbon stock changes and non-CO_2 emissions in the *project area*

Project year *t*	*Baseline* *carbon stock* changes		*Baseline* GHG emissions	
	annual $\Delta CBSLPA_t$	cumulative $\Delta CBSLPA$	annual $EBSLPA_t$	cumulative $EBSLPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1	-	-	-	-
2	-	-	-	-
…	-	-	-	-
T	-	-	-	-

Step 7: *Ex ante* estimation of actual *carbon stock* changes and non-CO_2 emissions in the *project area*

The goal of this step is to provide an *ex ante* estimate of *carbon stock* change under the *project scenario*, and, where included in the *baseline*, non-CO_2 emissions from *forest* fires.

81

Since actual changes will be subject to monitoring and verification, the rationale of estimating them at the beginning of a *crediting period* is to assist in guiding optimal implementation of emission reduction measures, and to allow reasonable projections of revenue to be made.

7.1 *Ex ante* estimation of actual *carbon stock* changes

These are due to the following:

7.1.1 Planned activities within the *project area*.

7.1.2 Unplanned *deforestation* that cannot be avoided.

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

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

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

b) Forest management for timber logging, fuel-wood collection or charcoal production; and,

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

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

If the project activities generate an increase in carbon stocks, the carbon stock change can always be conservatively ignored. However, accounting for carbon stock increase on areas projected to be deforested in the *baseline* case is optional in this methodology[49]. If the increase in carbon stocks is accounted, *ex post* monitoring is mandatory.

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

Mandatory accounting of significant carbon stock decreases:

If the REDD *project activity* includes planned *deforestation*, harvesting of timber[50], fuel-wood collection or charcoal production at levels greater than the *baseline* case, do the following:

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

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

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

82

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

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

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

d) Estimate the impacts of the planned activities on carbon stocks, as follows:

- Planned *deforestation*: Conservatively assume that 100% of the carbon stocks will be lost[51].
- Areas subject to planned logging, fuel-wood collection or charcoal production above the *baseline* case: Conservatively assume that the carbon stock of these areas will be the lowest of the production cycle according to the planned levels of extraction.

e) Summarize the result of the previous assessments and calculations in Tables 21.a – 21.d.

Table 21.a *Ex ante* estimated actual *carbon stock* decrease due to planned *deforestation* in the *project area*

Project year	Areas of planned *deforestation* x Carbon stock								Total carbon stock decrease due to planned *deforestation*	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = *Icl*		annual	cumulative
	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$\Delta CPDdPA_t$	$\Delta CPDdPA$
	ha	tCO_2e tCO_2-e ha^{-1}	ha	tCO_2e tCO_2-e ha^{-1}	ha	tCO_2e tCO_2-e ha^{-1}	ha	tCO_2e tCO_2-e ha^{-1}	tCO_2e tCO_2-e	tCO_2e tCO_2-e
1										
2										
. . .										
T										

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

83

Table 21.b ***Ex ante*** **estimated actual carbon stock decrease due to planned logging activities in the** ***project area***

Project year	Areas of planned logging activities x Carbon stock change (decrease)								Total carbon stock decrease due to planned logging activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$APLPA_{icl,t}$	$Ctot_{icl,t}$	$\Delta CPLdPA_t$	$\Delta CPLDPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

Table 21.c ***Ex ante*** **estimated actual** ***carbon stock*** **decrease due to planned fuel wood collection and charcoal production in the** ***project area***

Project year	Areas of planned fuel-wood & charcoal activities x Carbon stock change (decrease)								Total carbon stock decrease due to planned logging activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPFdPA_t$	$\Delta CPFdPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

84

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

Project year	Total carbon stock decrease due to planned *deforestation*		Total carbon stock decrease due to planned logging activities		Total carbon stock decrease due to planned logging activities		Total carbon stock decrease due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPDdPA_t$	$\Delta CPDdPA$	$\Delta CPLdPA_t$	$\Delta CPLdPA$	$\Delta CPFdPA_t$	$\Delta CPFdPA$	$\Delta CPAdPA_t$	$\Delta CPAdPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1								
2								
. . .								
T								

Optional accounting of significant carbon stock increase

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

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

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

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

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

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

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

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

85

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

h) Summarize the result of the previous assessments and calculations in Tables 22.a – 22.d below.

Table 22.a ***Ex ante* estimated carbon stock increase due to planned protection without harvest in the *project area***

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

Table 22.b ***Ex ante* estimated carbon stock increase following planned logging activities in the *project area***

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

86

Table 22.c *Ex ante* estimated carbon stock increase following planned fuel-wood and charcoal activities in the *project area*

Project year	Areas of planned fuel-wood and charcoal activities x Carbon stock change (increase up to maximum long-term average)								Total carbon stock increase due to planned fuel-wood and charcoal activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPFiPA_t$	$\Delta CPFiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

Table 22.d Total *ex ante* estimated carbon stock increase due to planned activities in the *project area*

Project year	Total carbon stock increase due to growth without harvest		Total carbon stock increase due to planned logging activities		Total carbon stock increase due to planned fuel-wood and charcoal activities		Total carbon stock increase due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPNiPA_t$	$\Delta CPNiPA$	$\Delta CPLiPA_t$	$\Delta CPLiPA$	$\Delta CPFiPA_t$	$\Delta CPFiPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1								
2								
. . .								
T								

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

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

To allow *ex ante* projections to be made, the project proponent shall make a conservative assumption about the effectiveness of the proposed project activities and estimate an Effectiveness Index (*EI*) between 0 (no effectiveness) and 1 (maximum effectiveness). The

87

estimated value of EI is used to multiply the *baseline* projections by the factor (1 - *EI*) and the result shall be considered the *ex ante* estimated emissions from unplanned *deforestation* in the project case.

$$\Delta CUDdPA_t = \Delta CBSL_t * (1 - EI) \quad (19)|$$
(20)

Where:

$\Delta CUDdPA_t$	Total *ex ante* actual carbon stock change due to unavoided unplanned *deforestation* at year *t* in the *project area*; tCO_2etCO_2-e
$\Delta CBSL_t$	Total *baseline* carbon stock change at year *t* in the *project area*; tCO_2etCO_2-e
EI	*Ex ante* estimated Effectiveness Index; %

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

Summarize the result of the previous assessments in Table 23

Table 23. *Ex ante* estimated net *carbon stock* change in the *project area* under the project scenario

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

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

Where *forest* fires have been included in the *baseline*, non-CO_2 emissions from biomass burning must be included in the *project scenario*. This is done by multiplying the *baseline* emissions by the factor (1 – *EI*). The results are presented in Table 24.

$$EBBPSPA_t = EBBBSPAL_t * (1 - EI)| \quad (21)$$

88

Where:

$EBBPSPA_t$	Total *ex ante* actual non-CO_2 emissions from forest fire due to unavoided unplanned *deforestation* at year *t* in the *project area*; tCO_2-e
$EBBBSPA_t$	Total non-CO_2 emissions from forest fire at year *t* in the *project area*; tCO_2-e
EI	*Ex ante* estimated Effectiveness Index; %

Table 24. Total *ex ante* estimated actual emissions of non-CO2 gases due to forest fires in the *project area*

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

89

7.3 Total *ex ante* estimations for the *project area*

Table 25. Total *ex ante* estimated actual net carbon stock changes and emissions of non-CO_2 gases due to forest fires in the *project area*

Project year	Total ex ante carbon stock decrease due to planned activities		Total ex ante carbon stock increase due to planned activities		Total ex ante carbon stock decrease due to unavoided unplanned *deforestation*		Total ex ante net carbon stock change		Total *ex ante* estimated actual non-CO_2 emissions from forest fires in the *project area*	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$	$\Delta CUDdPA_t$	$\Delta CUDdPA$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EBBPSPA_t$	$EBBPSPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1										
2										
. . .										
T										

Step 8: Estimation of potential decrease in *carbon stock* and increase in GHG emissions due to *leakage*

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

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

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

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

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

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

90

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

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

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

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

8.1.2 Nitrous oxide (N_2O) emissions from nitrogen fertilization; or

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

Where such activities and associated carbon stock changes and GHG emissions are not included in the project design, they must not be estimated.

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

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

Leakage prevention activities generating a decrease in *carbon stocks* should be avoided, but if such activities are necessary, they should be planned at locations that will be deforested in the *baseline* case during the *fixed baseline period* (within 10 years of the project start date), in which case the carbon stock decrease can be ignored as it would happen in any case within a short period of time.

If an area of forest not projected to be deforested during the fixed *baseline* period (or an area with higher carbon stock than the planned leakage prevention activity) needs to be sacrificed, the decrease in carbon stock associated to the leakage prevention activity must be estimated *ex ante*, and – if significant – measured *ex post* and accounted

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

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

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

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

91

d) Identify the forest and non-forest classes existing within these areas in the *baseline* case.

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

f) Report in Table 26.a the projected *baseline* carbon stock changes in the leakage management areas.

g) According to the planned interventions, estimate the projected carbon stocks in the leakage management areas under the project scenario. Use conservative growth projections. Report the result in Table 26.b

h) Calculate the net carbon stock changes that the planned leakage prevention measures are expected to occasion during the fixed crediting period and, optionally, the project crediting period. Report the results of the calculations in Table 26.c.

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

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

Table 26.a *Ex ante* estimated carbon stock change in leakage management areas in the *baseline* case

Project year	Carbon stock changes in leakage management areas in the *baseline* case								Total *baseline* C stock change	
	ID_{icl} = 1		ID_{icl} = 2		ID_{icl} = . . .		ID_{icl} = Icl		annual	cumulative
	$ABSLLK_{icl,t}$	$ctot_{icl}Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$ctot_{icl}Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$ctot_{icl}Ctot_{icl,t}$	$ABSLLK_{icl,t}$	$ctot_{icl}Ctot_{icl,t}$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

92

Table 26.b *Ex ante* estimated carbon stock change in leakage management areas in the project case

Project year	Carbon stock changes in leakage management areas in the project case								Total project C stock change	
	ID_{fcl} = 1		ID_{fcl} = 2		ID_{fcl} = . . .		ID_{fcl} = Fcl		annual	cumulative
	APSLKfcl,t	$Ctot_{fcl,t}$	*APSLKfcl,t*	$Ctot_{fcl,t}$	*APSLKfcl,t*	$Ctot_{fcl,t}$	*APSLKfcl,t*	$Ctot_{fcl,t}$	Δ *CPSLKt*	Δ *CPSLK*
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 26.c *Ex ante* estimated net carbon stock change in leakage management areas

Project year	Total C stock change in the *baseline* case		Total C stock change in the project case		Net carbon stock changes due to leakage prevention measures	
	annual	cumulative	annual	cumulative	annual	cumulative
	ABSLLK,t	*ABSLLK*	*DCPSLKt*	*DCPSLK*	Δ *CLPMLKt*	Δ *CLPMLK*
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0						
1						
2						
. . .						
T						

8.1.2 Estimation of N_2O emissions from nitrogen fertilization

To estimate emissions of nitrous oxide (N_2O) from nitrogen fertilization in leakage management areas, do the following:

a) Specify the annual areas that will require fertilization according to the planned activities in the leakage management areas.

b) Describe the types of fertilizers (organic, synthetic) that will be applied. Use Table 27.a and 27.b to report the key parameters of the fertilizers used that are required to perform the calculation of GHG emissions.

c) Determine the amount of *baseline* fertilization and the amount needed under the project scenario for each area. The difference must be considered for the calculation of the increase in GHG emissions.

93

d) Using Table 28, specify the amount of increased fertilization planned for each future year and type of fertilizer.

e) To estimate the increase in GHC emissions, the most recent version of the CDM-EB approved tool for "Estimation of direct nitrous oxide emissions from nitrogen fertilization" for A/R CDM project activities[52]must be used. Report the result of the calculations in Table 27.

Note: The notation $N_2O_{direct\text{-}N,t}$ used in the CDM-EB tool is replaced by the notation $EN2OdNLK_t$ in this methodology. The variable means "Direct N_2O emissions as a result of increased nitrogen application within *leakage* management areas at year *t*"[53].

Table 27.a Parameters of synthetic fertilizers

Type of fertilizer		Nitrogen content of synthetic fertilizer type *i* applied	Emission Factor for emissions from N inputs	Fraction that volatises as NH_3 and NO_x
		$NCSF_i$	*EF1*	*FracGASF*
ID_i	*Name*	gN per 100g fertilizer	$tN_2O\ tN^{-1}$	%

[52] Available at: http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html. When applying this tool in a REDD *project activity* read "*leakage management area*" and "*boundary of the leakage management area*" instead of "*project area*" and "*project boundary*".

[53] If some emissions above the *baseline* also occur in the *project area*, these must be included in the calculation of this parameter.

94

Table 27.a Parameters of organic fertilizers

Type of fertilizer		Nitrogen content of synthetic fertilizer type *i* applied	Emission Factor for emissions from N inputs	Fraction that volatises as NH_3 and NO_x
		$NCOF_j$	*EF1*	*FracGASF*
ID_j	*Name*	gN per 100g fertilizer	$tN_2O\ tN^{-1}$	%

Table 28. Total *ex ante* leakage N_2O emissions from nitrogen fertilization above the *baseline* in leakage management areas

Project year	Area and amount of synthetic fertilizer applied						Area and amount of organic fertilizer applied						Total *ex ante* N_2O emissions from nitrogen fertilization	
	ID_i =	1		ID_i =	. . .		ID_j =	1		ID_j =	. . .			
	$Afert_{i,t}$	MSF_{it}	FSN_t	$Afert_{i,t}$	MSF_{it}	FSN_t	$Afert_{j,t}$	MSF_{jt}	FSO_t	$Afert_{j,t}$	MSF_{jt}	FSO_t	$EN2OdNLK_t$ annual	$EN2OdNLK$ cumulative
	ha	$tN\ ha^{-1}$	tN	ha	$tN\ ha^{-1}$	tN	ha	$tN\ ha^{-1}$	tN	ha	$tN\ ha^{-1}$	tN	tCO_2-e	tCO_2-e
1														
2														
. . .														
T														

8.1.2 Estimation of CH_4 and N_2O emissions from grazing animals

To estimate emissions of methane (CH_4) and nitrous oxide (N_2O) from grazing animals in leakage management areas, do the following:

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

b) Briefly describe the types of animal, forage and manure management system. Use Table 29 to report the key parameters required to perform the calculation of GHG emissions.

95

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

d) Methods to estimate emissions from enteric fermentation and manure management are given in Appendix 4. Perform the final calculations using equation 22 and report the results using Table 30.

The GHG emissions are estimated as follows:

$$EgLK_t = ECH4ferm_t + ECH4man_t + EN2Oman_t \tag{22}$$

Where:

$EgLK_t$	Emissions from grazing animals in leakage management areas at year *t;* $tCO_2e\ yr^{-1}$
$ECH4ferm_t$	CH_4 emissions from enteric fermentation in leakage management areas at year *t*; $tCO_2e\ yr^{-1}$
$ECH4man_t$	CH_4 emissions from manure management in leakage management areas year *t*; $tCO_2e\ yr^{-1}$
$EN2Oman_t$	N_2O emissions from manure management in leakage management areas at year *t*; $tCO_2e\ yr^{-1}$
t	1, 2, 3 … *T* years of the project crediting period

96

Table 29. Parameters used for the *ex ante* estimation of GHG emissions from grazing activities

Parameter	Value used for calculations	Unit	Description
EF1		kg CH_4 $head^{-1}$ yr^{-1}	Enteric CH_4 emission factor for the livestock group
EF2		kg CH4 $head^{-1}$ yr^{-1}	Manure management CH_4 emission factor for the livestock group
EF3		kg N_2O-N (kg N^{-1})	Emission factor for N_2O emissions from manure management for the livestock group
EF4		kg N_2O-N (kg NH_3-N and NO_x-N emitted)$^{-1}$	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces
DBI		kg d.m. $head^{-1}$ day^{-1}	Daily biomass intake per head
Nex		kg N $head^{-1}$ yr^{-1}	Annual average N excretion per livestock head
Fracgas		kg NH_3-N and NO_x-N emitted (Kg N)$^{-1}$	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NO_x in the manure management phase

97

Table 30. *Ex ante* estimation of leakage emissions above the *baseline* from grazing animals in leakage management areas

Project year	*$Aforage_t$*	*$Pforage_t$*	*$Population_t$*	*$ECH4ferm_t$*	*$ECH4man_t$*	*$EdirN20man_t$*	*$EidN20man_t$*	*$EN2Oman_{,t}$*	annual *$EgLK_t$*	cumulative *$EgLK_t$*
	ha	kg d. m. yr^{-1}	Nr heads	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0										
1										
2										
3										

8.1.4 Total *ex ante* estimated carbon stock changes an increases in GHG emissions due to *leakage* prevention measures

Summarize the results of the previous estimations in Table 31, where only significant sources must be reported.

Table 31. *Ex ante* estimated total emissions above the *baseline* from leakage prevention activities

Project year	Net carbon stock changes due to leakage prevention measures		Total *ex ante* N_2O emissions from increased nitrogenate fertilization		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	annual	cumulative
	Δ *CLPMLKt*	Δ *CLPMLK*	$EN2OdNLK_t$	*EN2OdNLK*	$EgLK_t$	$EgLK_t$	$ELPMLK_t$	*ELPMLK*
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0								
1								
2								
3								
4								

8.2 *Ex ante* estimation of the decrease in *carbon stocks* and increase in GHG emissions due to activity displacement leakage

Activities that will cause *deforestation* within the *project area* in the *baseline* case could be displaced outside the project boundary due to the implementation of the REDD *project activity*. Where no broader sub-national or national program exists that is monitoring, reporting and verifying emissions from *deforestation* outside the *project area* under a UNFCCC or VCS acknowledged program, activity displacement leakage must be estimated and, if significant, accounted.

To estimate activity displacement leakage two approaches can be used:

- Approach 1: Time discount approach.
- Approach 2: Monitoring of *deforestation* in the leakage belt area.

Approach 1: Time discount approach

Under the time discount approach, activity displacement *leakage* is assumed to be the difference between actual emission reductions and their net present value for climate change mitigation. The net present value is calculated based on the assumption that the *project activity* will cause a 100% displacement of the *baseline deforestation.* As a consequence, the overall *deforestation* rate will not change compared to the *baseline* situation. However, the total area of unprotected *forest* in the region or country where the project is located will be reduced due to the implementation of the REDD *project activity*, which will anticipate the time point when *deforestation* will end and reduce the total area deforested in the long-term.

Using a 100-year time horizon, a discount rate of 1%, and the atmospheric carbon decay curve from the version of the Bern model used in the IPCC's Third Assessment Report, Fearnside et al. (2000)[54] and Fearnside (2009)[55] calculated the net present value of avoiding the emission of one ton of CO_2 as being 0.6 tCO_2e. Thus, under option 1, *leakage* due to displacement of *baseline* activities is assumed to be 40% of the GHG emission reductions achieved by the *project activity* within the *project area*:

$$\Delta CADL_t = 0.4 * (\Delta CBSLPA_t - \Delta CPSPA_t) \quad (23)$$

$$EADL_t = 0.4 * EBSLPA_t \quad (24)$$

Where:

$\Delta CADL_t$	Total decrease in carbon stocks due to activity displacement leakage at year *t*; $tCO_2\text{-e } yr^{-1}$
$\Delta CBSLPA_t$	Total net *baseline* carbon stock change within the *project area* at year *t*; $tCO_2\text{-e } yr^{-1}$
$\Delta CPSPA_t$	Total net actual carbon stock change within the *project area* at year *t*; $tCO_2\text{-e } yr^{-1}$
$EADL_t$	Total increase in GHG emissions due to displaced forest fires at year *t*; $tCO_2\text{-e } yr^{-1}$
$EBSLPA_t$	Total *baseline* GHG emissions due forest fires at year *t*; $tCO_2etCO_2\text{-e } yr^{-1}$
t	1, 2, 3, … *t*, a year of the crediting period; dimensionless

Approach 2: Monitoring of *deforestation* in the leakage belt area

If carbon stocks in the leakage belt area decrease during the crediting period this will indicate that leakage due to displacement of *baseline* activities has occurred. Leakage due to activity displacement can thus be estimated by *ex post* monitoring of *deforestation* in the leakage belt area. *Ex ante*, however, activity displacement leakage can only be guessed based on the anticipated combined effectiveness of the proposed leakage prevention measures and project activities.

[54] Fearnside, P.M., D.A. Lashof and P. Moura-Costa. 2000. Accounting for time in mitigating global warming through land-use change and forestry. Mitigation and Adaptation Strategies for Global Change, 5(3): 239-270.

[55] Fearnside, P.M., 2009. Carbon Benefits from Amazonian forest reserves: leakage accounting and the value of time. Mitigation and Adaptation Strategies for Global Change, 14:557-567.

100

This shall be done by multiplying the estimated *baseline* carbon stock changes for the *project area* ($\Delta CBSLPA_t$) by a Displacement Leakage Factor (*DLF*) representing the percentage% of *deforestation* expected to be displaced outside the project boundary in the project case[56].

If emissions from forest fires have been included in the *baseline*, the *ex ante* emissions from forest fires due to activity displacement leakage will be calculated by multiplying *baseline* forest fire emissions in the *project area* ($EBSLPA_t$) by the same Displacement Leakage Factor (*DLF*) used to estimate the decrease in carbon stocks.

Report the *ex ante* estimated leakage due to activity displacement in Table 32.

Table 32: *Ex ante* estimated *leakage* due to activity displacement

Project year	Total *ex ante estimated* decrease in carbon stocks due to displaced *deforestation*		Total *ex ante estimated* increase in GHG emissions due to displaced forest fires	
	annual $\Delta CADLK_t$ tCO_2-e	cumulative $\Delta CADLK$ tCO_2-e	annual $EADLK_t$ tCO_2-e	cumulative $EADLK$ tCO_2-e
1				
2				
. . .				
T				

8.3 *Ex ante* estimation of total *leakage*

Summarize the resultresults of all significant sources of leakage in Table 3233.

[56] If *deforestation* agents do not participate in *leakage* prevention activities and project activities, the Displacement Factor shall be 100%. Where *leakage* prevention activities are implemented, the factor shall be equal to the proportion of the *baseline* agents estimated to be given the opportunity to participate in *leakage* prevention activities and project activities.

101

Table 33. *Ex ante* estimated total *leakage*

Project year	Total *ex ante* N_2O emissions from increased nitrogenate fertilization		Total *ex ante* GHG emissions from increased grazing activities		Total *ex ante estimated* increase in GHG emissions due to displaced forest fires		Total *ex ante estimated* decrease in carbon stocks due to displaced *deforestation*		Net carbon stock changes due to leakage prevention measures		Total net carbon stock change due to leakage		Total net increase in emissions due to leakage	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$EN2OdNLK_t$	$EN2OdNLK$	$EgLK_t$	$EgLK_t$	$EADLK_t$	$EADLK$	$\Delta\ CADLK_t$	$\Delta\ CADLK$	$\Delta\ CLPMLKt$	$\Delta\ CLPMLK$	$\Delta\ CLK_t$	$\Delta\ CLK$	ELK_t	ELK
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1														
2														
. . .														
T														

Step 9: ***Ex ante* total net anthropogenic GHG emission reductions**

9.1 Significance assessment

Using the latest EB-CDM approved "Tool for testing significance of GHG emissions in A/R CDM project activities" determine the significance of each of the *ex ante* calculated carbon stock changes and GHG emissions. Report the results of the analysis in the PD.

Only significant sources and pools need to be accounted in the calculation of *ex ante* and *ex post* net anthropogenic GHG emission reductions. These pools and sources must be included in the monitoring plan.

9.2 *Ex-ante* estimated total net anthropogenic GHG emission reductions

The net anthropogenic GHG emission reduction of the REDD *project activity* is calculated as follows:

$$\Delta REDD_t = (\Delta CBSL_t + EBSL_t) - (\Delta CPS_t + EPSL_t) - (\Delta CLK_t + ELK_t) \quad (25)$$

Where:

$\Delta REDD_t$ — *Ex ante* estimated net anthropogenic greenhouse gas emission reduction attributable to the REDD *project activity* at year t; tCO_2e

$\Delta CBSL_t$ — *Ex ante* estimated net *baseline* carbon stock changes in the *project area* at year t; tCO_2e

$EBSL_t$ — *Ex ante* estimated *baseline* GHG emissions in the *project area* at year t; tCO_2e

ΔCPS_t — *Ex ante* estimated net carbon stock changes in the *project area* at year t; tCO_2e

Note: for *ex post* estimations replace *"ex ante"* by *"ex post"*

$EPSL_t$ — *Ex ante* estimated emissions in the *project area* at year t; tCO_2e

Note: for *ex post* estimations replace *"ex ante"* by *"ex post"*

ΔCLK_t — *Ex ante* estimated net leakage carbon stock changes at year t; tCO_2e

Notes:

- If the cumulative sum of ΔCLK_t within a fixed *baseline* period is > 0, ΔCLK_t shall be set to zero.
- For *ex post* estimations replace *"ex ante"* by *"ex post"*

ELK_t — *Ex ante* estimated leakage emissions at year t; tCO_2e

Note: for *ex post* estimations replace *"ex ante"* by *"ex post"*

9.3 Calculation of *ex-ante* Voluntary Carbon Units (VCUs)

The number of Voluntary Carbon Units (VCU_t) to be generated through the proposed REDD *project activity* at year t is equivalent to $REDD_t$ ($VCU_t = \Delta REDD_t$). However, the number of Voluntary Carbon Units (VCUs) to be made available for trade at time t is calculated as follows:

$$VCU_t = VCUT_t + VCUB_t \tag{26}$$

$$VCBU_t = (\Delta CBSL_t - \Delta CPS_t) * RF_t \tag{27}$$

Where:

$VCU_{,t}$ Total number of Voluntary Carbon Units (VCUs) at time t; tCO_2-e

$VCUB_t$ Number of Voluntary Carbon Units (VCUs) to be withheld in the VCS Buffer at time t; tCO_2-e

$VCUT_t$ Number of Voluntary Carbon Units (VCUs) to be made available for trade at time t; tCO_2-e

RF_t Proportion of $VCU_{,t}$ to be withheld in the VCS Buffer; %

Note: *RF* is a risk factor to be determined using the latest version of the VCS-approved “Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination”.

Present the result of the calculations in Table 34.

104

Table 34. *Ex ante* estimated net anthropogenic GHG emission reductions ($\Delta REDD_t$) and Voluntary Carbon Units (VCU_t)

Project year	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 antropogenic GHG emission reductions		*Ex ante* VCUs tradable		*Ex ante* VCUs buffer	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLPA_t$	$\Delta CBSLPA$	$EBSLPA_t$	$EBSLPA$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EPSPA_t$	$EPSPA$	ΔCLK_t	ΔCLK	ELK_t	ELK	$\Delta REDD_t$	$\Delta REDD$	$VCUT_t$	$VCUT$	$VCUB_t$	$VCUB$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
1																		
2																		
. . .																		
T																		

Part 3 – Methodology for verification and re-validation of the baseline

The *ex post* methodology (to be implemented immediately after project start) includes two main tasks:

1) Monitoring of carbon stock changes and GHG emissions for periodical verifications within the fixed *baseline* period; and,

2) Monitoring of key *baseline* parameters for revisiting the *baseline* at the end of the *fixed baseline period*.

Task 1: Monitoring

There are three main monitoring tasks:

1.1 Monitoring of actual carbon stock changes and GHG emissions within the *project area*.

1.2 Monitoring of leakage.

1.3 *Ex post* calculation of net anthropogenic GHG emission reductions.

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

a) Technical description of the monitoring task.

b) Data to be collected.

c) Overview of data collection procedures.

d) Quality control and quality assurance procedure.

e) Data archiving.

f) Organization and responsibilities of the parties involved in all the above.

1.1 Monitoring of actual carbon stock changes and GHG emissions within the *project area*

This task involves:

1.1.1 Monitoring of project implementation.

1.1.2 Monitoring of land-use and land-cover change.

1.1.3 Monitoring of *carbon stocks* and non-CO_2 emissions.

1.1.4 Monitoring of natural disturbances.

1.1.1 Monitoring of project implementation

Project activities implemented within the *project area* should be consistent with the management plans of the *project area*. All maps and records generated during project implementation should be conserved and made available to VCS verifiers for inspection.[57].

1.1.2 Monitoring of land-use and land-cover change within the *project area*

The categories of changes that may be subject to MRV are summarized in Table 35.

Table 35. Categories subject to MRV

ID	Type	Conditions under which monitoring is mandatory	Explanations
I	Area of forest land converted to non-forest land.	Mandatory in all REDD project activities	
II	Area of forest land undergoing carbon stock decrease	Mandatory only for REDD project activities having planned logging, fuel-wood collection and charcoal production activities above the *baseline*	Change in carbon stock must be significant according to ex ante assessment, otherwise monitoring is not required
III	Area of forest land undergoing carbon stock increase	Mandatory only for REDD project activities wishing to claim carbon credits for carbon stock increase	Increase must be significant according to ex ante assessment and can only be accounted on areas that will be deforested in the *baseline* case

If the *project area* is located within a region that is subject to MRV under a VCS or UNFCCC approved program, the data generated by the exiting monitoring program must be used.

If the *project area* is located within a region that is subject to a monitoring program that is approved or sanctioned by the national or sub-national government, the data generated by the existing program must be used, unless they are not applicable according to the criteria listed below:

a) Monitoring occurs in the entire *project area*, and – if the project must monitor a leakage belt – in the leakage belt.

b) If data from the existing monitoring program are used to periodically revisit the *baseline*, monitoring must occur in the entire *reference region* at least at the beginning, middle and end of the fixed *baseline* period.

[57] Digital map layers should be stored in a common GIS database using common projection, datum and vector and raster file formats.

107

c) At least Category I is subject to monitoring (conversion of forest land to non-forest land).

d) If the project must do a monitoring of other categories (II and/or III) and these are not included in the existing program, the existing program can only be used for monitoring category I, and the project proponent must implement a separate monitoring program for category II and/or III.

e) Monitoring will occur during the entire fixed *baseline* period.

f) Monitoring methods are transparently documented and are similar to those used to determine the *baseline* of the REDD *project activity*.

g) Monitoring must be accessible for inspection by VCS accredited verifier.

If no existing monitoring program exists or can be used, monitoring must be done by the project proponent or outsourced to a competent entity. Methods used to monitor LU/LC change categories must be similar to those explained in Part I, Step 2.4.

1.1.3 Monitoring of *carbon stock* changes and non-CO_2 emissions from forest fires

Monitoring of carbon stock changes

In most cases, the *ex* ante estimated average carbon stocks per LU/LC class and carbon stock change factors per LU/LC change category will not change during a fixed *baseline* period and monitoring of carbon stocks will not be necessary.

Monitoring of carbon stocks is mandatory only in the following forest classes:

a) Forest classes within areas subject to significant carbon stock decrease in the project scenario according to the *ex ante* assessment. These will be areas subject to planned *deforestation* and planned harvest activities, such as logging for timber, fuel wood collection and charcoal production. In these areas, carbon stocks must be estimated at least once after each harvest event.

b) Forest classes within areas subject to significant carbon stock increase according to the *ex ante* assessment. This is only mandatory if the project proponent wishes to claim credits for the carbon stock increase.

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

Some project proponents may wish to make additional carbon stock measurements during project implementation to gain accuracy and credits. If new and more accurate *carbon stock* data become available, these can be used to estimate the net anthropogenic GHG emission reduction of the subsequent fixed *baseline* period. For the current fixed *baseline* period, new data on *carbon stocks* can only be used if they are validated by an accredited VCS verifier. If new data are used in the current fixed *baseline* period, the *baseline* must be recalculated using the new data.

108

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 21.a	*Ex post* carbon stock decrease due to planned and unplanned *deforestation* in the *project area*.
Table.21.b	*Ex post* carbon stock decrease due to planned logging activities.
Table 21 c	*Ex post* carbon stock decrease due to planned fuel-wood and charcoal activities.
Table 21 d	Total *ex post* carbon stock decrease due to planned and unplanned activities.
Table 22.a	*Ex post* carbon stock increase due to growth without harvest.
Table 22.b	*Ex post* carbon stock increase following planned logging activities
Table 22.c	*Ex post* carbon stock increase following planned fuel-wood and charcoal activities
Table 22.d	Total *ex post* carbon stock increase
Table 23	*Ex post* total net carbon stock change in the *project area*

Monitoring of non-CO_2 emissions from forest fires

Non-CO_2 emissions from forest fires are subject to monitoring only if emissions from forest fire were included in the *baseline*. In this case, under the project scenario it will be necessary to monitor the variables of Table 18 within the *project area* and to report the results in Table 19.

1.1.4 Monitoring of natural disturbances

Monitoring of natural disturbances and their impacts on carbon stocks and GHG emissions is optional.

Natural disturbances such as tsunami, sea level rise, volcanic eruption, landslide, flooding, permafrost melting, pest, disease, etc. can have a significant impact on *carbon stocks* and GHG emissions[58]. Such changes can be abrupt or gradual, and, - when significant, - the project proponent may wish to factor them out from the estimation of *ex post* net anthropogenic GHG emission reductions.

- Where natural disturbances reduce the area of forest land, measure the boundary of the polygons of lost forest and exclude the area within such polygons from the *project*

[58] When the 1997-1998 El Niño episode provoked severe droughts in the Amazon and Indonesia, large areas of tropical forest burned, releasing 0.2 to 0.,4 Gt of carbon to the atmosphere (de Mendonça *et al.*, 2004; Siegert *et al.*, 2001; Page *et al*., 2002). If droughts become more severe in the future through more frequent and severe el Niño episodes (Trenberth and Hoar, 1997; Timmermann *et al*., 1999), or the dry season becomes lengthier due to *deforestation*-induced rainfall inhibition (Nobre *et al*., 1991; Silva-Dias *et al*., 2002) or there are rainfall reductions due to climate change (White *et al*., 1999; Cox *et al*., 2000), then substantial portions of the 200 Gt of carbon stored globally on tropical forest trees could be transferred to the atmosphere in the coming decades (Santilli *et al*., 2005).

109

area in both, the *baseline* and project scenarios. The boundary of such polygons shall be determined using the same data sources, methods and procedures used to monitor *deforestation* in the *project area*.

- Where natural disturbances have an impact on carbon stocks, measure the boundary of the polygons where such changes happened and the change in carbon stock within each polygon. Assume that a similar carbon stock change would have happened in the forest under the *baseline* case (if the polygon is already deforested in the *baseline*, assume no carbon stock change in the *baseline*).

Where gradual changes in carbon stocks are likely to be significant (e.g. due to the effects of climate change), monitoring of carbon stocks in permanent sample plots located at places not expected to change due to human interventions may be considered. Methods described in Annex 3 shall be used. Factoring-out would then imply changing the *ex ante* estimated carbon stocks and emission factors. If evidence is collected demonstrating that natural disturbances have had a significant impact on carbon stocks and GHG emissions within a fixed *baseline* period, data from such evidence can be used to estimate the net anthropogenic GHG emission reduction of the subsequent fixed *baseline* period. For the current fixed *baseline* period, such data on carbon stocks and GHG emissions can only be used if they are validated by an accredited VCS verifier.

1.1.5 *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 in:

Table 25: *Ex post* estimated actual net changes in carbon stocks and emissions of GHG gases in the *project area*

1.2 Monitoring of *leakage*

Monitoring of leakage is not required if the *project area* is located within a region that is monitoring, reporting and accounting emissions from *deforestation* under a VCS or UNFCCC registered program.

In all other circumstances, the sources of leakage identified as significant in the *ex ante* assessment are subject to monitoring. Two sources of *leakage* are potentially subject to monitoring:

1.2.1 Decrease in carbon stocks and increase in GHG emissions associated with *leakage* prevention measures; and,

1.2.2 Decrease in carbon stocks and increase in GHG emissions due to activity displacement leakage.

110

1.2.1 Monitoring of carbon stock changes and GHG emissions associated to *leakage* prevention measures

Monitoring of the sources of emissions associated to *leakage* prevention measures must happen with the methods and tools described in Part 2, (Step 8.1) of the methodology and the methods described in Appendix 3 for monitoring carbon stock changes.

Results must be reported using the same formats and tables used in the *ex ante* assessment (see below):

Table 26.b *Ex post* carbon stock change in leakage management areas.

Table 26.c *Ex post* net carbon stock change in leakage management areas[59].

Table 27.a *Ex post* parameters of synthetic fertilizers applied.

Table 27.b *Ex post* parameters of organic fertilizers applied.

Table 28. Total *ex post* N_2O emissions from nitrogen fertilization in leakage management areas.

Table 29. *Ex post* parameters for estimating GHG emissions from grazing activities.

Table 30. *Ex post* estimation of emissions from grazing animals in leakage management areas.

Table 31. *Ex post* estimation of net carbon stock changes and GHG emissions from leakage prevention activities.

1.2.2 Monitoring of carbon stock decrease and increases in GHG emissions due to activity displacement leakage

Monitoring of carbon stock changes and GHG emissions will not be necessary if the time discount approach has been used in the *ex ante* assessment of activity displacement leakage. Under this approach, use equations 23 and 24 to estimate *ex post* activity displacement leakage.

If monitoring of the leakage belt was the approach chosen in the *ex ante* assessment, monitoring of carbon stock changes and GHG emissions in the leakage belt area will be required, as explained below.

Monitoring of carbon stock changes

Deforestation of forest land in the *leakage* belt area will be considered activity displacement leakage.

[59] Calculations of total net carbon stock changes in leakage management areas use the ex ante estimated *baseline* carbon stock changes in the leakage management area and the measured ex post carbon stock changes. If the cumulative value of the carbon stock change within a fixed *baseline* period is > 0, $\Delta CLPMLK_t$ shall be set to zero.

111

Activity data for the leakage belt area must be determined using the same methods applied to monitoring *deforestation* activity data (Category I) in the *project area*. Monitoring of Category II and III outside the *project area* is not required because no credits are claimed for avoided degradation under this methodology.

The result of the *ex post* estimations of carbon stock changes must be reported using the same table formats used in the *ex ante* assessment of *baseline* carbon stock changes in the *project area*:

Table 15.a *Ex post* carbon stock change in pre-*deforestation* forest classes in the leakage belt .

Table 15.b *Ex post* carbon stock change in post-*deforestation* non-forest classes in the leakage belt.

Table 15.c *Ex post* total net carbon stock changes in the leakage belt.

Where strong evidence can be collected that *deforestation* in the leakage belt is attributable to *deforestation* agents that are not linked to the *project area*, the detected *deforestation* may not be attributed to the *project activity* and considered leakage. The operational entity verifying the monitoring data shall determine whether the documentation provided by the project proponent represents sufficient evidence to consider the detected *deforestation* as not attributable to the *project activity* and therefore not leakage.

Monitoring of increases in GHG emissions

Increases in GHG emissions must only be estimated and accounted if emissions from forest fires are included in the *baseline*.

To estimate the increased GHG emissions due to forest fires in the leakage belt area the assumption is made that forest clearing is done byoccurs due to forest burning the *forest*. The parameter values used to estimate emissions shall be the same used for estimating forest fires in the *baseline* (Table 18), except for the initial carbon stocks (*Cab*, *Cdw*, *Cl*), which shall be those of the initial forest classes burned in the leakage belt area.

Report the result of the estimations using the same table formats used in the *ex ante* assessment of *baseline* GHG emissions from forest fires in the *project area*:

Table 18. Parameters used to calculate emissions from forest fires in the leakage belt area.

Table 19. *Ex post* estimated non-CO_2 emissions from forest fires in the leakage belt area

1.2.3 Total *ex post* estimated leakage

Summarize the results of all *ex post* estimations of leakage using the same table format used for the *ex ante* assessment:

Table 32. Total *ex post* estimated leakage

112

<u>Note</u>: Monitoring of activity displacement leakage will become obsolete aton the date when a VCS or UNFCCC registered program is monitoring, reporting, verifying and accounting emissions from *deforestation* in a broader area encompassing the *project area*.

1.3 *Ex post* estimated net anthropogenic GHG emission reductions

The calculation of *ex post* net anthropogenic GHG emission reductions is similar to the e*x ante* calculation with the only difference that *ex post* measured emissions must be used in the case of the *project scenario*[60] and *leakage*.

Report the *ex post* estimated net anthropogenic GHG emissions and calculation of Voluntary Carbon Units (VCU_t, $VCUB_t$ and $VCUT_t$) using the same table format used for the *ex ante* assessment:

Table 34. *Ex post* estimated net anthropogenic GHG emission reductions and VCUs**.**

Task 2: Revisiting the *baseline* projections for future *fixed baseline periods*

Baselines, independently from the approach chosen to establish them, must be revisited over time because agents, drivers and underlying causes of *deforestation* change dynamically. Frequent and unpredicted updating of the *baseline* can create serious market uncertainties. Therefore, the *baseline* should be revisited every 5 to 10 years.

When revisiting the *baseline*:

2.1 Update information on agents, drivers and underlying causes of *deforestation;*

2.2 Adjust the land-use and land-cover change component of the *baseline; and,*

2.3 Adjust, as needed, the carbon stock component of the *baseline.*

2.1 Update of the information on agents, drivers and underlying causes of *deforestation*

Information on agents, drivers and underlying causes of *deforestation* in the *reference region* must be collected periodically, as these are essential for improving future *deforestation* projections and the design of the *project activity*.

- Collect information that is relevant to understand *deforestation* agents, drivers, and underlying causes.
- Redo step 3 of the *ex ante* methodology.
- New data on the spatial variables used to create factor maps and modeling the *deforestation* risk must be collected as they become available. The new data must be

[60] Further explanation, see Appendix 1.

113

used to create updated spatial datasets and updated factor maps for the subsequent fixed *baseline* period.

- Changes in the overall *baseline deforestation* model are allowed, as long as they are implemented according to the methodology steps described in Part 2 of the methodology and subject to validation by an accredited VCS verifier.

2.2 Adjustment of the land-use and land-cover change component of the *baseline*

If an applicable sub-national or national *baseline* becomes available during the fixed *baseline* period, it must be used for the subsequent period. Applicability of a sub-national or national *baseline* is determined by applying the criteria of Table 2. If such an applicable *baseline* is not available, the *baseline* projections must be revisited and adjusted as necessary.

The two components of the *baseline* projections that must be reassessed are:

2.2.1 The annual areas of *baseline deforestation*; and

2.2.2 The location of *baseline deforestation*.

2.2.1 Adjustment of the annual areas of *baseline deforestation*

At the end of each *crediting period*, the *baseline deforestation* rate of the *reference region*, *leakage belt* and *project area* need to be revisited and eventually adjusted for the subsequent *crediting period*. The adjusted *baseline rates* must be submitted for an independent validation.

Adjustments are made using the methods described in Part 2, Step 4 of the methodology and using the data obtained from monitoring LU/LC changes in the *reference region* during the past *fixed baseline period* and, where applicable, any updated information on the variables included in the estimation of the projected areas of *baseline deforestation*.

2.2.2 Adjustment of the location of projected *baseline deforestation*

Using the adjusted projections for annual areas of *baseline deforestation* and any improved spatial data for the creation of the factor maps included in the spatial model, the location of the projected *baseline deforestation* must be reassessed using the methods explained in Part 2, Step 4 of the methodology.

Note: If the boundary of the leakage belt area was assessed using equation (1) or any other spatial model, the boundary of the leakage belt will have to be reassessed at the end of each fixed *baseline* period using the same methodological approaches used in the first period. This will be required until monitoring of leakage will become unnecessary[61].

[61] Monitoring of leakage will become obsolete on the date when a VCS or UNFCCC registered program is monitoring, reporting, verifying and accounting emissions from *deforestation* in a broader area encompassing the *project area*.

114

2.3 Adjustment of the carbon stock component of the *baseline*

Adjusting the carbon stock component of the *baseline* will not be necessary in most cases. However, improved carbon stock data are likely to become available over time and if this is the case, they must be used when revisiting the *baseline* projections. Methods to measure and estimate carbon stocks are described in Appendix 3.

115

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119

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120

APPENDIX 1
DEFINITION OF TERMS FREQUENTLY USED IN THE METHODOLOGY

Activity Data is the annual area (ha yr^{-1}) lost or acquired by a *LU/LC class* at a given year *t* within the project *crediting period*, or the annual area of a *category of LU/LC -change* for a given year *t*.

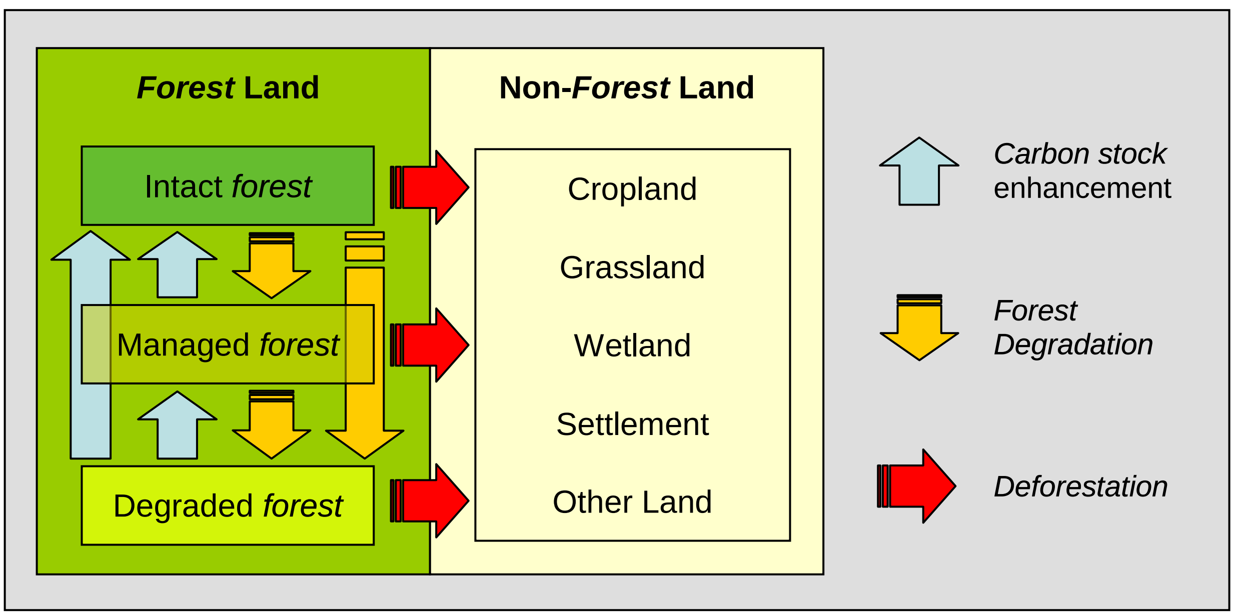
Actual Emission Level is the sum of *carbon stock* changes and GHG emissions that occurs within the boundary of the *project area* under the proposed REDD *project activity*.

Baseline Scenario is the expected change in land use and land cover (LU/LC) within the boundary of the *project area* in the absence of any *project activity* designed to reduce emissions from *deforestation*, *forest degradation*, or enhance *carbon stocks*.

Baseline is the sum of *carbon stock* changes and GHG emissions that would occur within the boundary of the *project area* in the absence of the proposed REDD *project activity*.

Broad Category is the term used in this methodology to identify three main *categories* of LU/LC-change: *deforestation*, *forest degradation* (with *carbon stock* decrease) and *forest regeneration* (with *carbon stock* increase) (Figure A1-1):

Figure A1-1. *Broad categories* of land-use and land-cover change



Carbon Density (or *carbon stock* per hectare) is the amount of carbon (as CO_2-e) per hectare (ha^{-1}) estimated to be present in the accounted carbon pools of a *LU/LC Class* at year *t*.

Carbon Stock is the *carbon density* of an area times the number of hectares in the area.

Carbon Stock Change Factor: see "*Emission Factor*".

121

Category of LU/LC-Change (or simply "*category*") is the change from one *LU/LC class* to another that occurs during a given period of time.

Category is the term used in IPCC reports to refer to specific sources of emissions or removals of greenhouse gases. Under the AFOLU sector, "categories" are land-use / land-cover (LU/LC) transitions. RED methodologies deal with the following categories:

(a) *Forest* Land to *Forest* Land (degradation and regeneration of *forest* land remaining *forest* land).

(b) *Forest* Land to Crop Land (*deforestation* followed by agriculture).

(c) *Forest* Land to Grassland (*deforestation* followed by pasture).

(d) *Forest* Land to Settlements (*deforestation* followed by settlements).

(e) *Forest* Land to Wetlands (*deforestation* followed by wetlands).

(f) *Forest* Land to Other Land (*deforestation* followed by other land).

Activities that convert non-*forest* land back to *forest* (Crop Land to *Forest* Land, Grassland to *Forest* Land, etc.) are considered afforestation and reforestation and are excluded from REDD methodologies.

Class. See *LU/LC Class*.

Crediting Period is the period of time for which the net GHG emission reductions or removals will be verified, which under the VCS is equivalent to the project lifetime. The project must have a robust operating plan covering this period. The project *crediting period* shall be between 20 and 100 years.

Deforestation is the direct, human-induced, and long-term (or permanent) conversion of *forest* land to non-*forest* land[62]. It occurs when at least one of the parameter values used to define "*forest* land" is reduced from above the threshold for defining "*forest*" to below this threshold for a period of time that is longer than the period of time used to define "*temporarily un-stocked*"[63]. For example, if a country defines a *forest* as having a crown cover greater than 30% and "*temporarily un-stocked*" as a maximum period of 3 years, then *deforestation* would not be recorded until the crown cover is reduced below 30% for at least three consecutive years[64]. Country should develop and report criteria

[62] Forest area and carbon stock losses due to natural disturbances (landslides, consequences of volcanic eruptions, and see level rise, among other) are not considered "*deforestation*".

[63] According to IPCC (GPG LUUCF, 2003, Chapter 4.2.6.2.) "The identification of units of land subject to *deforestation* activities requires the delineation of units of land that:
(a) Meet or exceed the size of the country's minimum forest area (i.e., 0.05 to 1 ha); and
(b) Have met the definition of forest on 31 December 1989; and
(c) Have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced *deforestation*."

[64] *Deforestation* can be the result of an abrupt event (*deforestation* = forest → non-forest), in which case the change in land-cover and land-use occurs immediately and simultaneously; or of a process of progressive degradation (*deforestation* = forest → degraded forest → non-forest), in which case the change in land-cover

122

by which temporary removal or loss of tree cover can be distinguished from *deforestation*.

Eligible Land. To avoid double counting of emission reductions, land areas registered under the CDM, VCS or any other carbon trading scheme (both voluntary and compliance-oriented) should be transparently reported and excluded from the *project area*.

Emission Factor (or *Carbon Stock Change Factor*) is the difference between the *carbon density* of the two *LU/LC classes* describing a *category of LU/LC-change*.

Fixed Baseline Period is the period of time for which the validated *baseline* is fixed, which under the VCS can be up to 10 years. After this period of time, the *baseline* must be reassessed using a VCS approved methodology.

Forest is a land with woody vegetation consistent with the thresholds used to define "*forest* land" in the country where the RED *project activity* will be implemented. Where the country has adopted a *forest* definition for the Kyoto Protocol, the minimum thresholds of the vegetation indicators (minimum area, tree crown cover and height)[65] used for defining "*forests*", as communicated by the DNA[66] consistent with decision 11/CP.7 and 19/CP.9, should be used. Otherwise, the definition used to define "*Forest* Land" in the national GHG inventory should be used.

Land defined as "*forest* land" can include areas that do not, but at maturity *in situ* could potentially reach, the thresholds used to define "*forest* land". To distinguish between "non-*forest*" (and hence "deforested") and "*temporarily un-stocked*" areas in managed *forests*, the definition of "*forest*" should include the maximum period of time that the woody vegetation can remain below the thresholds used to define "*forest* land". This maximum period can be specific for each *category* of land-use / land-cover change (LU/LC-change). For instance, it could be zero years for conversion from "*forest* land to crop land", but up to 5 or more years for transitions between *forest* classes (e.g. age classes)[67].

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occurs when one of the parameters used for defining "forest land" falls below its minimum threshold, but the change in land-use may have already occurred or will occur later (e.g. use of the land for the production of crops or grazing animals). Land-use is thus not a reliable indicator for identifying a forest class or for defining a category of change.

[65] "Forest is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 per cent with trees with the potential to reach a minimum height of 2 – 5 metres at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10 – 30 per cent or tree height of 2 – 5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest".

[66] DNA = Designated National Authority of the Clean Development Mechanism.

[67] Project proponents should report on how they distinguish between *deforestation* and areas that remain forests but where tree cover has been removed temporarily, notably areas that have been harvested or have been subject to other human or natural disturbance but for which it is expected that forest will be replanted or regenerate naturally. See IPCC GPG LULUCF, 2003, Chapter. 4.2.6.2.1 for further guidance on this issue.

123

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

Forest degradation is "*forest* land remaining *forest* land" but gradually losing *carbon stocks* as a consequence of direct-human intervention (e.g. logging, fuel-wood collection, fire, grazing, etc.)[68]. Units of *forest* land subject to degradation are allocated to different *forest classes* over time, with each successive *class* having a lower *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two contiguous *forest classes* in the degradation sequence (Figure A1-2).

Forest management. Areas subject to sustainable *forest management* (with logging activities) represent a particular *class* of "degraded *forest*". An undisturbed natural *forest* that will be subject to sustainable *forest management* will lose part of its carbon, but the loss will partially recover over time. In the long-term, a sustainable harvesting and re-growth cycle will maintain a constant average *carbon density* in the *forest*. Since this average *carbon density* is lower than in the original *forest*, sustainably managed *forests* can be considered a degraded *forest class*.

Depending on the magnitude and timeframe of the *carbon stock* changes, managed *forests* could be classified into one single "managed *forest*" *class* (with a *carbon density* equivalent to the average of the entire management cycle) or to different sub-*classes* representing different average carbon densities (Figure A1-2).

Forest Regeneration is "*forest* land remaining *forest* land" but gradually enhancing its *carbon stock* as a consequence of direct-human intervention. Units of *forest* land subject to regeneration are allocated to different *forest classes* over time, with each successive *forest* class having a higher *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two *forest classes*.

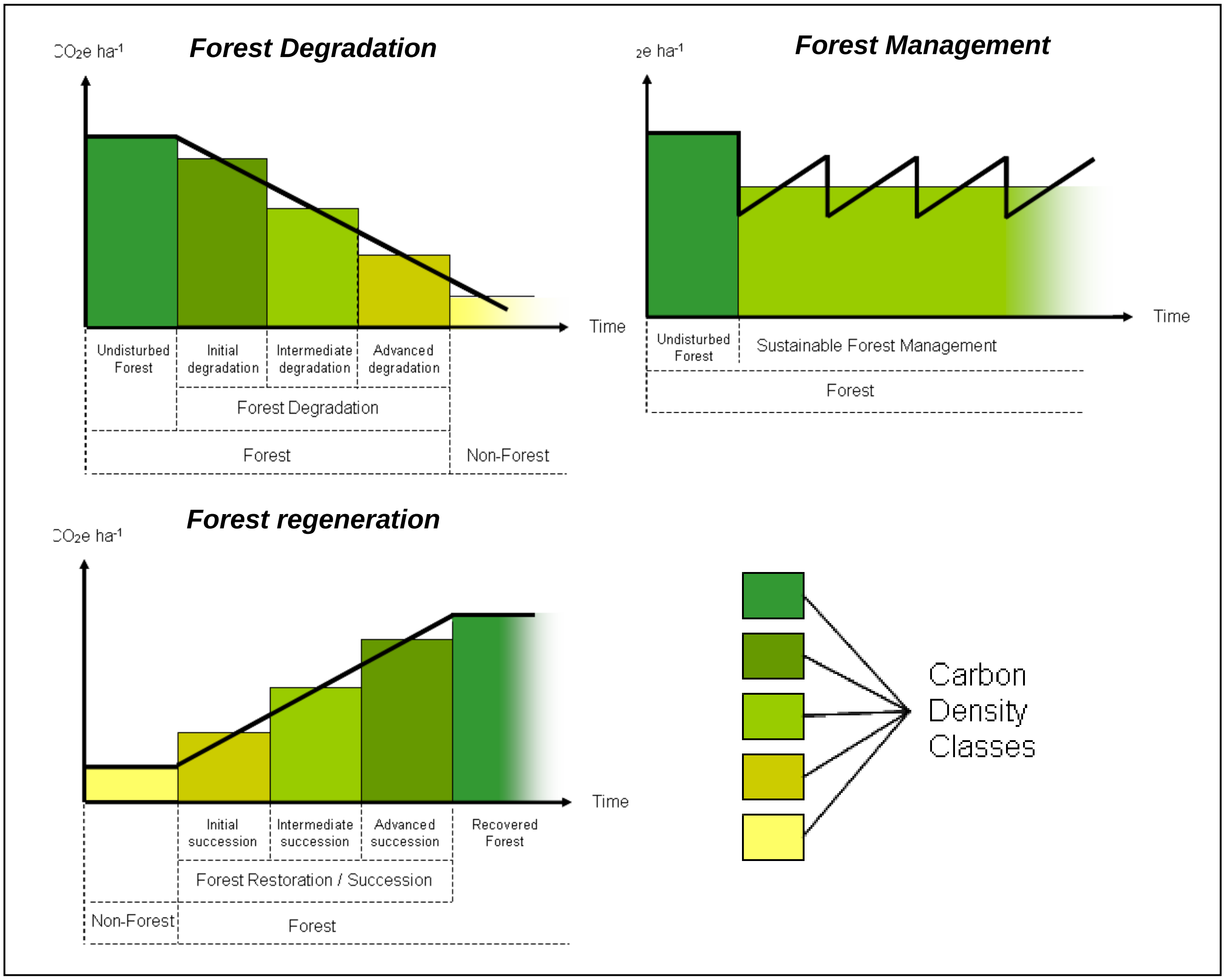
Frontier Deforestation is the conversion of *forest* land to non-*forest* land occurring when the agricultural frontier expands as a result of improved access to *forest* into areas with relatively little human activity.

68 According to IPCC GPG LULUCF "*forest degradation*" is "a direct, human-induced, long-term (persisting for *X* years or more) or at least *Y%* of forest carbon stock [and forest values] since time *T* and not qualifying as *deforestation*". Note that *X*, *Y%* and *T* are not quantified. See IPCC 2003 (Report on Definitions and Methodological Options to Inventory Emissions from Direct Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, Chapter 2.2) for a discussion on the definition of "*forest degradation*", in particular Table 2.1 for alternative definitions of direct human-induced *forest degradation*.

124

Historical Reference Period is a time period preceding the starting date of the proposed REDD *project activity*. It is analyzed to determine the magnitude of *deforestation* and *forest degradation* in the *reference region* and to identify agents and drivers of DD and the chain of events leading to land-use / land-cover change. In order to be useful for understanding recent and likely future DD trends, the starting date of the *historical reference period* should be selected between 10 and 15 years in the past, and the end date as close as possible to present.

Figure A1-2. *Carbon density* in "*forest* land remaining *forest* land" (living tree biomass)



Leakage is the decrease in *carbon stocks* and the increase in GHG emissions attributable to the implementation of the REDD *project activity* that occurs outside the boundary of the *project area*.

125

Leakage belt is the geographical area surrounding or adjacent to the *project area* containing only *forest* land remaining *forest* land in the *baseline* case in which activity displacement *leakage* could occur.

Leakage management area is an area (or set of areas) specifically designated by the project proponent to implement activities designed to reduce the risk of activity displacement leakage.

LU/LC Class (or simply "*class*") is a unique combination of land use and land cover having a specific *carbon density*.

LU/LC Polygon is a discrete area falling into a single *LU/LC class*.

Monitoring period is the period of time (in years) between two monitoring and verification events. Typically it is a fraction of the *crediting period*. The minimum duration is one year and the maximum is the duration of the *crediting period*.

Mosaic Deforestation is the conversion of *forest* land to non-*forest* land occurring in a patchy pattern where human population and associated agricultural activities and infrastructure (roads, towns, etc.) are spread out across the landscape and most areas of *forest* within such a configured region or country are practically already accessible.

Planned Deforestation is the legally authorized conversion of *forest* land to non-*forest* land occurring in a discrete area of land. *Deforestation* within an area can be planned (designated and sanctioned) or unplanned (unsanctioned). *Planned deforestation* can include a wide variety of activities such as national resettlement programs from non-forested to forested regions; a component of a national land plan to reduce the *forest* estate and convert it to other industrial-scale production of goods such as soybeans, pulpwood plantations, and oil palm plantations; or plans to convert well-managed community-owned *forests* to other non-*forest* uses. Other forms of *planned deforestation* could also include decisions by individual land owners, whose land is legally zoned for agriculture, to convert their selectively logged *forest* to crop production. These *planned deforestation* activities would be a component of some land planning or management document and could be readily verified.

Project Activity is the series of planned steps and activities by which the proponent intends to reduce *deforestation* and *forest degradation* and/or enhance *forest regeneration*.

Project Area is the area or areas of land on which the proponent will undertake the *project activities*. No lands on which the *project activity* will not be undertaken can be included in the *project area*.

Project Scenario is the expected change in land use and land cover within the boundary of the *project area* resulting from the undertaking of the *project activity*.

Project Term is the projected lifetime of the REDD *project activity*, which under the VCS is equivalent to the project *crediting period*.

Reference Region is the spatial delimitation of the analytic domain from which information about *deforestation* and degradation agents, drivers and LU/LC-change is obtained,

126

projected into the future and monitored. The *reference region* includes the *project area*[69] and is defined by the project proponent using transparent criteria. It must contain *LU/LC classes* and *deforestation* agents and drivers similar to those found in the *project area* under the *baseline* and *project scenarios*.

[69] The methodology thus adopts a so called "Stratified Regional *Baseline*" (SRB) approach, which has been recommended in recent literature (Sathaye and Andrasko, 2007; Brown *et al.*, 2007a)

127

APPENDIX 2
INDICATIVE TABLES

Table 1. Guidance on carbon pool selection depending on the *land-use / land-cover change category* considered[70]

Type of land-use / land-cover transition	Living biomass (trees)		Dead organic matter			Soil
	Above-ground	Below-ground	Wood products	Dead wood	Litter	Organic matter
Forest to cropland	+++	++	+	+	+	+
Forest to pasture	+++	++	+	+	+	
Forest to shifting cultivation	+++	++		+		
Forest to degraded *forest*	+++	++	+			
+++ = include always; ++ = inclusion recommended; + = inclusion possible						

Table 2. Present availability of optical mid-resolution (10-60m) sensors
(Brown *et al*., 2007a)[71]

Nation	Satellite & sensor	Resolution & coverage	Cost (archive[72])	Feature
U.S.A.	Landsat-5 TM	30 m 180×180 km^2	600 US$/scene 0.02 US$/km^2	Images every 16 days to any satellite receiving station. Operating beyond expected lifetime.
U.S.A.	Landsat-7 ETM+	30 m 60×180 km^2	600 US$/scene 0.06 US$/km^2	On April 2003 the failure of the scan line corrector resulted in data gaps outside of the central portion of images, seriously compromising data quality
U.S.A./Japan	Terra ASTER	15 m 60×60 km^2	60 US$/scene 0.02 US$/km^2	Data is acquired on request and is not routinely collected for all areas
India	IRS-P2 LISS-III & AWIFS	23.5 & 56 m		Experimental craft shows promise, although images are hard to acquire
China/Brazil	CBERS-2 HRCCD	20 m		Experimental; Brazil uses on-demand images to bolster their coverage.
Algeria/China/Nigeria/Turkey/U.K.	DMC	32 m 160×660 km^2	3000 €/scene 0.03 €/km^2	Commercial; Brazil uses alongside Landsat data
France	SPOT-5 HRVIR	5-20 m 60×60 km^2	2000 €/scene 0.5 €/km^2	Commercial Indonesia & Thailand used alongside Landsat data

70 Modified from Brown, S., F. Achard, R. de Fries, G. Grassi, N. Harris, M. Herold, D. Mollicone, D. Pandey, T. Pearson, D. Shoch, 2007. Reducing Greenhouse Gas emission from *deforestation* and Degradation in Developing Countries: A Sourcebook of Methods and Procedures for Monitoring, Measuring and Reporting (Draft Version, 10.November, 2007).

71 See also see http://www.cbmjournal.com/content/4/1/7, from August 2009. See Table 2 on p. 23

72 Some acquisitions can be programmed (e.g., DMC, SPOT). The cost of programmed data is generally at least twice the cost of archived data.

128

Table 3. Example of a potential land use-change matrix

Final \ **Initial**		*Forest* land – *Class 1*	*Forest* land – *Class 2*	*Forest* land – *Class 3*	*Forest* land – *Class 4*	*Forest* land – *Class 5*
***Forest* Land**	*Class 1*	*Category 1/1*	*Category 2/1*	*Category 3/1*	*Category 4/1*	*Category 5/1*
	Class 2	*Category 1/2*	*Category 2/2*	*Category 3/2*	*Category 4/2*	*Category 5/2*
	Class 3	*Category 1/3*	*Category 2/3*	*Category 3/3*	*Category 4/3*	*Category 5/3*
	Class 4	*Category 1/4*	*Category 2/4*	*Category 3/4*	*Category 4/4*	*Category 5/4*
	Class 5	*Category 1/5*	*Category 2/5*	*Category 3/5*	*Category 4/5*	*Category 5/5*
Grassland	*Class 6*	*Category 1/6*	*Category 2/6*	*Category 3/6*	*Category 4/6*	*Category 5/6*
Cropland	*Class 7*	*Category 1/7*	*Category 2/7*	*Category 3/7*	*Category 4/7*	*Category 5/7*
Wetland	*Class 8*	*Category 1/8*	*Category 2/8*	*Category 3/8*	*Category 4/8*	*Category 5/8*
Settlement	*Class 9*	*Category 1/9*	*Category 2/9*	*Category 3/9*	*Category 4/9*	*Category 5/9*
Other Land	*Class 10*	*Category 1/10*	*Category 2/10*	*Category 3/10*	*Category 4/10*	*Category 5/10*

Table 4. Example of a land-use / land-cover change matrix

Final \ **Initial**			*Forest* land											**Final area**
			Old growth *forests*		Degraded old growth *forest*			Secondary *forest*			Plantations			
			Intact	managed	initial	intermediate	advanced	initial	intermediate	advanced	young	mid	mature	
Forest Land	Old-growth	Intact	100											**100**
		managed	1	5										**6**
	Degraded	Initial	1		2									**3**
		intermediate			2	1								**3**
		advanced				2	3							**5**
	Secondary	Initial						2						**2**
		intermediate						1	3					**4**
		advanced							1	1				**2**
	Plantations	Young					1	1	1		1		1	**5**
		Mid									1	2		**3**
		Mature											1	**1**
Grassland		unimproved	1	1	1	2		1	1	1				**8**
		improved				1	1							**2**
Cropland				1		1		2	3	3				**10**
Wetland														**0**
Settlement														**0**
Other Land														**0**
Initial Area			**103**	**7**	**5**	**7**	**5**	**7**	**9**	**5**	**2**	**2**	**2**	**154**

129

Net Change	-3	-1	-2	-4	0	-5	-5	-3	3	1	-1	0

Notes:

- Numbers represent hectares or *activity data* (in this case numbers are for illustrative purposes only, they do not represent any real case).
- Column and rows totals show net conversion of each LU/LC-class.
- "Initial" indicates the area of the LU/LC-class at the starting date of the period assessed, and "Final" the area of the class at the end date of the assessment period.
- Net changes (bottom rows) are the final area minus the initial area for each of the LU/LC-classes shown at the head of the corresponding column.
- Blank entries indicate no LU/LC-change the period assessed.

Table 5. Approximate values of daily biomass intake (d. m. – dry mass) for different type of animals[73]

Animal Type		Daily Feed Intake (MJ head^{-1} day^{-1})	Daily Biomass Intake (kg d. m. head^{-1} day^{-1})
Sheep	Developed Countries	20	2.0
	Developing Countries	13	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).			

[73] Taken form AR-AM0003 version 2

130

Box 1: Geomod

Geomod is a land-use land-cover change simulation model implemented in Idrisi, a GIS software developed by Clark University (Pontius *et al.*, 2001; Brown *et al.*, 2007). Geomod has been used frequently to analyze *baseline scenario*s of *deforestation* at continental scale for Africa, Asia and Latin America; at the country scale for Costa Rica and India; and at local scale within India, Egypt, Unites States and several countries in Latin America (Pontius and Chen, 2006).

Geomod is a grid-based model that predicts the transition from one *LU/LC class* to another *LU/LC class*, i.e. the location of grid cells that change over time from *class* 1 to *class* 2. Hence, Geomod can be used to predict areas likely to change from *forest class* 1 to non-forest *class* 2 (*deforestation*) over a given time.

Geomod creates the LU/LC-change risk map empirically, by using several driver images and the land-cover map from the beginning time. For example, Geomod's *deforestation* risk maps have relatively high values at location that have biogeophysical attributes similar to those of the deforested land (= "developed land" in Geomod's jargon) of the beginning time, and has relatively low values at locations that have biogeophysical attributes similar to those of forested land ("non-developed" land) of the beginning time.

Box 2. Example of Simple Error Propagation analysis (Tier 1 method)
(Taken from Brown *et al.*, 2007)

Carbon pool	Average carbon stock t C ha^{-1}	95% CI t C ha^{-1}
Above-ground biomass	113	11
Dead wood	18	3
Litter	7	2

Therefore the total stock is 138 t C/ha and the uncertainty = $\sqrt{11^2 + 3^2 + 2^2} = 11.6 tC/ha$

	Mean	95% CI	Uncertainty %
Area (ha)	8564	1158	14
Caron stock (tC ha^{-1})	138	11,6	8

Therefore the total carbon stock over the stratum is: 8564 * 138 = 1,181,832 t C

And the uncertainty = $\sqrt{14^2 + 8^2} = 15.9\%$
15.9% of 1,181,832 = 188,165 t C

131

APPENDIX 3
Methods to Estimate Carbon Stocks

Sampling framework

The sampling framework, including sample size, plot size, plot shape and plot location should be specified in the PD.

Areas to be sampled in *forest classes* should be at locations expected to be deforested according to the *baseline* projections.

The sampling areas for *non-forest classes* should be selected within the *reference region* at locations that represent a chrono-sequence of 10 to 30 years since the *deforestation* date.

Temporary or permanent plots

Plots can be temporary or permanent depending on the specific project circumstances, interests and needs, but in general temporary plots should be sufficient.

Where changes in *carbon stocks* are to be monitored, permanent sampling plots are recommended. Permanent sample plots are generally regarded as statistically efficient in estimating changes in *forest carbon stocks* because typically there is high covariance between observations at successive sampling events. However, it should be ensured that the plots are treated in the same way as other lands within the project boundary, e.g., during logging operations, and should not be destroyed over the monitoring interval. Ideally, staff involved in *forest management* activities should not be aware of the location of monitoring plots. Where local markers are used, these should not be visible.

Permanent plots may also be considered to reduce the uncertainty of the average *carbon density* of a *forest class* undergoing *carbon stock* changes due to management and to detect changes in *carbon stocks* induced by climate change or large-scale natural disturbances (as in Part 3, Task 1, Step 1.2.4).

Definition of the sample size and allocation among *LU/LC-classes*

The number of sample plots is estimated as dependent on accuracy, variability of the parameter to estimate in each class and costs. The sample size calculation also corresponds to the method of samples drawn without replacement. Where at the beginning of a REDD *project activity* accurate data for sample size estimation and allocation are not available, the sampling size can initially be estimated by using a desired level of accuracy (10% of sampling error at 95% confidence level), and by allocating the estimated sample size proportionally to the area of each *class*[74], using respectively equations 1 and 2. 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), which also accounts for the cost of

[74] Loetsch, F. and Haller, K. 1964. Forest Inventory. Volume 1. BLV-VERLAGS GESE LLSCHAFT, München.

132

sampling (see equations A3-3 and A3-4).

Equation A3-1 was chosen because it works with percentages rather than absolute units (biomass, carbon, or CO_2), and coefficient variation data could be easier to find in the literature at the beginning of a *project activity*. The initial allocation of the sample plots shall be proportional to the area of the *LU/LC -classes*, but with minimum of 5 plots per class. The t-student for a 95% confidence level is approximately equal to 2 when the number of sample plot is over 30. As the first step, use 2 as the t –student value, and if the resulting "*n*" is less than 30, use the new "*n*" to get a new t-student value and conduct the new estimation of the sample size. This process can be repeated until the calculated *n* is stabilized.

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

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

Where:

cl	=	1, 2, 3, …. *Cl* LU/LC classes
Cl	=	Total number of LU/LC classes
t_{st}	=	t-student value for a 95% confidence level (initial value t = 2)
n	=	total number of sample units to be measured (in all LU/LC classes)
E%	=	allowable sample error in percentage (±10%)
CV%	=	the highest coefficient of variation (%) reported in the literature from different volume or biomass forest inventories in forest plantations, natural forests, agro-forestry and/or silvo-pastoral systems.
n_i	=	number of samples units to be measured in LU/LC class cl that is allocated proportional to the size of the class. If estimated $n_{cl} < 3$, set $n_{cl} = 3$.
N_i	=	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of *class cl* by the measurement plot area.
N	=	population size or maximum number of possible sample units (all LU/LC classes), $N = \sum_{cl=1}^{Cl} N_{cl}$

In equation A3-3 the standard deviation of each *LU/LC class* (S_{cl}) shall be determined using the actual data from the latest field measurement. The allowable error is an absolute value, and can be estimated as ±10% of the observed overall average *carbon stock* per hectare. It is possible to reasonably modify the *LU/LC class* limits and the sample size after each monitoring event based on the actual variation of the *carbon stock* changes determined from taking "*n*" sample plots. Where costs for selecting and measuring plots are not a significant consideration then the calculation and allocation of the sample size can be simplified by

133

setting C_{cl} equal to 1 across all *LU/LC classes*.

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

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

Where:

cl	=	1, 2, 3, … Cl LU/LC classes
Cl	=	total number of LU/LC classes
t_{st}	=	t-student value for a 95% confidence level, with n-2 degrees of freedom
E	=	allowable error (±10% of the mean)
S_{cl}	=	standard deviation of LU/LC class *cl*
n_{cl}	=	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to $W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}}$. If $n_{cl} < 3$, set $n_{cl} = 3$.
W_{cl}	=	N_{cl}/N
n	=	total number of sample units to be measured (in all LU/LC classes)
N_{cl}	=	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of LU/LC class *cl* by the measurement plot area
N	=	population size or maximum number of possible sample units (all strata), $N = \sum_{cl=1}^{Cl} N_{cl}$
C_i	=	cost to select and measure a plot of the LU/LC class *cl*

Sample plot size

The plot area *a* has major influence on the sampling intensity, time and resources spent in the field measurements. The area of a plot depends on the stand density. Therefore, increasing the plot area decreases the variability between two samples. According to Freese (1962), the relationship between coefficient of variation and plot area can be denoted as follows:

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

Where a_1 and a_2 represent different sample plot areas and their corresponding coefficient of variation (*CV*). Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same precision level. Usually, the size of plots is

134

between 100 m^2 for dense stands and 1000 m^2 for open stands[75].

Plot location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more "convenient" positions), the permanent sample plots shall be located systematically with a random start, which is considered good practice in IPCC GPG-LULUCF. This can be accomplished with the help of a GIS platform and a GPS in the field. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plots shall be recorded and archived.

The sampling plots should be as evenly distributed as possible. For example, if one stratum consists of three geographically separated sites, and then:

- Divide the total stratum area by the number of plots, resulting in the average area represented by each plot; and,
- 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.

Estimation of *carbon stocks*

The total average *carbon stock* per hectare (= *carbon density*) in a *LU/LC class* is estimated by the following equation:

$$Ctot_{cl} = Cab_{cl} + Cbb_{cl} + Cdw_{cl} + Cl_{cl} + Csoc_{cl} - Cwp_{cl} \qquad \text{(A3-6)}$$

Where:

$Ctot_{cl}$ = Average carbon stock per hectare in all accounted carbon pools of the LU/LC - class *cl*; tCO_2-e ha^{-1}

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

Cab_{cl} = Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

Cbb_{cl} = Average carbon stock per hectare in the below-ground biomass carbon pool of the *LU/LC class cl*; tCO_2-e ha^{-1}

Cdw_{cl} = Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

Cl_{cl} = Average carbon stock per hectare in the litter carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

75 It is recommended to use sample plots of equal area for the strata. This methodology cannot be used if sample plots area varies within the same stratum. Only the density of mature trees should be considered.

135

$Csoc_{cl}$ = Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class *cl*; $tCO_2e\ ha^{-1}$

Cwp_{cl} = Average carbon stock per hectare in the wood products carbon pool of the LU/LC class *cl*;

Note: See methodology Part 2 on mandatory carbon pools.

Estimation of *carbon stocks* in the living biomass carbon pools (Cab_{cl} and Cbb_{cl})

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

However, there might be situations where *carbon stocks* in the non-tree vegetation component are significantly increased in the *LU/LC -classes* adopted after *deforestation* (e.g. coffee plantations). Under such circumstances, *carbon stocks* in the non-tree vegetation component should be estimated[76].

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

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

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

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

Where:

Cab_{cl} = Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

$Cabt_{cl}$ = Average *carbon stock* per hectare in the above-ground tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

$Cabnt_{cl}$ = Average *carbon stock* per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

Cbb_{cl} = Average *carbon stock* per hectare in the below-ground biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

$Cbbt_{cl}$ = Average *carbon stock* per hectare in the below-ground tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

$Cbbnt_{cl}$ = Average carbon stock per hectare in the below-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

Tree component ($Cabt_{cl}$ and $Cbbt_{cl}$)

[76] The same carbon pools are to be estimated for the two classes of a LU/LC-change category.

136

The *carbon stock* of trees can be estimated using: (a) Existing *forest* inventory data; or (b) Direct field measurements.

(a) Estimations using *forest* inventory data
(See the most recent GOFC-GOLD sourcebook for REDD for more details)

Forest inventory data typically comes in two different forms: (1) Stand tables and (2) Stock tables.

(a.1) 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 (explained later).

Stand tables often include trees with a minimum diameter of 30 cm or more, which essentially ignores a significant amount of carbon particularly for younger *forests* or heavily logged. To overcome this problem Gillespie *et al.* (1992) developed a technique that can be used to estimate the number of trees in lower diameter classes (see Box 1).

Box 1. Adding diameter classes to truncated stand tables

DBH-Class cm	Midpoint Diameter cm	Number of Stems per ha Nr
10-19	15	-
20-29	25	-
30-39	35	35.1
40-49	45	11.8
50-59	55	4.7
…	…	…

DBH class 1 = 30-39 cm, DBH class 2 =40-49 cm
Ratio = 35.1/11.8 = = 2.97
Therefore, the number of trees in the 20-29 cm class is:
2.97 x 35.1 = 104.4
To calculate the 10-19 cm class:
104.4/35.1 = 2.97,
2.97 x 104.4 = 310.6

(a.2) Stock tables indicate the volume of merchantable timber by diameter class or total per hectare. If volume data are just for commercial species do not use them for estimating *carbon stocks*, because a large and unknown proportion of the total volume is excluded.

The biomass density can be calculated from Volume Over Bark (*VOB*) by multiplying this value with the Biomass Conversion and Expansion Factor (*BCEF*). When using this

137

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 FL AFOLU guidelines, and those relevant to tropical humid broadleaf and pine *forests* are shown in the Table 1.

Table 1. Values of *BCEF* for application to volume data
(Modified by Brown *et al.* (2007a) from Table 4.5 in IPCC GL AFOLU)

Forest type	Growing stock volume –*average* and range (*VOB*, m^3/ha)						
	<20	21-40	41-60	61-80	80-120	120-200	>200
Natural broadleaf	4.0 2.5-12.0	2.8 1.8-304	2.1 1.2-2.5	1.7 1.2-2.2	1.5 1.0-1.8	1.3 0.9-1.6	1.0 0.7-1.1
Conifer	1.8 1.4-2.4	1.3 1.0-1.5	1.0 0.8-1.2	0.8 0.7-1.2	0.8 0.6-1.0	0.7 1.6-0.9	0.7 0.6-0.9

In cases where the definition of *VOB* does not match exactly the definition given above, Brown *et al.* (2007b) recommend the following:

- If the definition of *VOB* also includes stem tops and large branches then the lower bound of the range for a given growing stock should be used;
- If the definition of *VOB* has a large minimum top diameter or the *VOB* is comprised of trees with particularly high basic wood density then the upper bound of the range should be used.

Forest inventories often report volumes for trees above a minimum *DBH*. To include the volume of *DBH* classes below the minimum *DBH*, Brown *et al.* (2007a) propose Volume Expansion Factors (*VEF*). However, due to large uncertainties in the volume of smaller *DBH* classes, inventories with a minimum diameter that is higher than 30 cm should not be used. Volume expansion factors range from about 1.1 to 2.5, and are related to the *VOB*30 as follows to allow conversion of *VOB*30 to a *VOB*10 equivalent:

- For *VOB*30 < 250 m^3/ha use the following equation:

$$VEF = Exp(1.300 - 0.209 * \ln(VOB30)) \qquad \text{(A3-9)}$$

- For *VOB*30 > 250 m^3/ha use *VEF* = 1.9

See Box 2 for a demonstration of the use of the *VEF* correction factor and *BCEF* to estimate biomass density.

138

Box 2. Use of volume expansion factor (*VEF*) and biomass conversion and expansion factor (*BCEF*)

Tropical broadleaf *forest* with a VOB30 = 100 m^3/ha

(1) Calculate the *VEF*:
VEF = Exp(1.300 - 0.209*Ln(100)) = 1.40

(2) Calculate *VOB*10:
*VOB*10 = 100 m^3/ha x 1.40 = 140 m^3/ha

(3) Take the *BCEF* from the table 7 above:
BCEF for tropical hardwood with growing stock of 140 m^3/ha = 1.3

(4) Calculate above-ground biomass density:
= 1.3 x 140 = 182 t/ha

Below-ground tree biomass (roots) is almost never measured, but instead is included through a relationship to above-ground biomass (usually a root-to-shoot ratio). If the vegetation strata correspond with tropical or subtropical types listed in Table 2 (modified by GOFC-GOLD, 2009 from Table 4.4 in IPCC GL AFOLU to exclude non-*forest* or non-tropical values and to account for incorrect values) then it makes sense to include roots.

Table 2. Root to shoot ratios
(Modified by GOFC-GOLD, 2009 from Table 4.4. in IPCC GL AFOLU)

Domain	Ecological Zone	Above-ground biomass	Root-to-shoot ratio	Range
Tropical	Tropical rain*forest*	<125 $t.ha^{-1}$	0.20	0.09-0.25
		>125 $t.ha^{-1}$	0.24	0.22-0.33
	Tropical dry *forest*	<20 $t.ha^{-1}$	0.56	0.28-0.68
		>20 $t.ha^{-1}$	0.28	0.27-0.28
Subtropical	Subtropical humid *forest*	<125 $t.ha^{-1}$	0.20	0.09-0.25
		>125 $t.ha^{-1}$	0.24	0.22-0.33
	Subtropical dry *forest*	<20 $t.ha^{-1}$	0.56	0.28-0.68
		>20 $t.ha^{-1}$	0.28	0.27-0.28

(b) Estimations using direct field measurements

Two methods are available to estimate the *carbon stock* of trees: (1) Allometric Equations method, and (2) Biomass Expansion Factors (*BEF*). The Allometric Equations method should be favored over the *BEF* method. However, if no biomass equations are available for a given species or *forest* type, the *BEF* method shall be used.

139

(b.1) <u>Allometric method</u>

1. In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly, depending on the form of the allometric equation, the height of all the trees above a minimum *DBH*.

2. Choose or establish the appropriate allometric equations for each species or species group *j*.

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

Where:

$TBab_j$	=	above-ground biomass of a tree of species, or species group, or forest type *j*, kg $tree^{-1}$
<u>Note:</u>		the unit (Kg $tree^{-1}$) could also be t $tree^{-1}$ or t ha^{-1}, depending on the type of allometric equation.
$f_j(DBH,H)_{ab}$	=	an allometric equation for species, or group of species, or forest type *j*, linking above-ground tree biomass (in kg $tree^{-1}$ – see the note above) to diameter at breast height (*DBH*) and possibly tree height (*H*).

The allometric equations are preferably local-derived and species-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4.A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the *project area* but outside the sample plots, a few trees of different species and sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species: the greater the heterogeneity the more trees are required. If resources permit, the carbon content can be determined in the laboratory. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as tree diameter and total height (see Chapter 4.3 in GPG LULUCF). Also generic allometric equations can be used, as long as it can be proven that they are conservative.

3. Estimate the *carbon stock* in the above-ground biomass of all trees measured in the permanent sample plots using the allometric equations selected or established for each

140

species or group of species.

$$TCab_{tr} = TBab_{tr} \cdot CF_j \qquad \text{(A3-11)}$$

Where:

$TCab_{,tr}$	=	*Carbon stock* in above-ground biomass of tree *tr*; kgC tree^{-1} (or t C tree-^{1})
$TBab_{tr}$	=	Above-ground biomass of tree *tr*; kg tree^{-1} (or t tree-^{1})
CF_j	=	Carbon fraction for tree *tr*, of species, group of species or forest type *j*; tC (t d. m.)$^{-1}$

4. Calculate the *carbon stock* in above-ground biomass per plot on a per area basis. Calculate by summing the *carbon stock* in above-ground biomass of all trees within each plot and multiplying by a plot expansion factor that is proportional to the area of the measurement plot. This is divided by 1,000 to convert from kg to tons.

$$PCab_{pl} = \frac{\left(\sum_{tr=1}^{TR_{pl}} TCab_{tr} \cdot XF\right)}{1000} \qquad \text{(A3-12)}$$

$$XF = \frac{10{,}000}{AP} \qquad \text{(A3-13)}$$

Where:

$PCab_{pl}$	=	Carbon stock in above-ground biomass in plot *pl*; tC ha^{-1}
$TCab_{tr}$	=	Above-ground biomass of tree *tr*; kg tree^{-1} (or t tree-^{1})
XF	=	Plot expansion factor from per plot values to per hectare values; dimensionless
AP	=	Plot area; m^2
tr	=	1, 2, 3, … TR_{pl} number of trees in plot *pl*; dimensionless

5. Calculate the average *carbon stock* by averaging across all plots within a *LU/LC class*.

$$Cab_{cl} = 44/12 * \frac{\sum_{pl=1}^{PL_{cl}} PCab_{pl}}{PL_{cl}} \qquad \text{(A3-14)}$$

Where:

Ca_{cl}	=	Average carbon stock per hectare in above-ground biomass in LU/LC class *cl*; tCO_2-e ha^{-1}.

141

$PCab_{pl}$	=	Carbon stock in above-ground biomass in plot *pl*; tC ha^{-1}
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_{cl} plots in LU/LC class c*l*; dimensionless
PL_{cl}	=	Total number of plots in LU/LC class c*l*; dimensionless

6. Estimate the *carbon stock* in the below-ground biomass of tree *tr* using root-shoot ratios and above-ground *carbon stock* and apply steps 4 and 5 to below-ground biomass.

$$TCbb_{tr} = TCab_{tr} \cdot R_j \tag{A3-15}$$

$$PCbb_{pl} = \frac{\left(\sum_{tr=1}^{TR} TCbb_{tr} \cdot XF \right)}{1000} \tag{A3-16}$$

$$Cbb_{cl} = \frac{\sum_{pl=1}^{PL_{cl}} PCbb_{pl}}{PL_{cl}} * 44/12 \tag{A3-17}$$

Where:

$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree *tr*; kg C $tree^{-1}$ (or t C tree-^{1})
$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree *tr*; kg C $tree^{-1}$ (or t C tree-^{1})
R_j	=	Root-shoot ratio appropriate for species, group of species or forest type *j*; dimensionless
$PCbb_{pl}$	=	Carbon stock in below-ground biomass in plot *pl*; tC ha^{-1}
XF	=	Plot expansion factor from per plot values to per hectare values
tr	=	1, 2, 3, … TR_{pl} number of trees in plot *pl*; dimensionless
Cbb_{cl}	=	Average carbon stock per hectare in below-ground biomass in *LU/LC class cl*; tCO_2-e ha^{-1}
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_l plots in LU/LC class *cl*; dimensionless
PL_{cl}	=	total number of plots in LU/LC class *cl*; dimensionless

(b.2) <u>Biomass Expansion Factor (*BEF*) Method</u>

1. In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly,

142

depending on the form of the volume equation, the height of all the trees above a minimum *DBH*.

2. Estimate the volume of the commercial component per each tree based on locally derived equations by species, species group or forest type. Then, sum for all tree within a plot, and express it as commercial volume per unit of area (m^3 ha^{-1}). It is also possible to combine step b.1 and step b.2 if there are available field instruments that measure volume per hectare directly (e.g. a Bitterlich relascope). The volume per plot is an ancillary variable, and it may be needed in some cases to estimate the proper biomass expansion factor or the root-shoot ratio.[77]

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

$$V_{pl} = \sum_{tr=1}^{TR} V_{tr} \cdot XF \tag{A3-19}$$

$$XF = \frac{10{,}000}{AP} \tag{A3-20}$$

Where:

V_{tr}	=	Commercial volume of tree *tr*; m^3 $tree^{-1}$
V_{pl}	=	Commercial volume of plot *pl*; m^3 $plot^{-1}$
$f_j(DBH,H)_V$	=	a commercial volume equation for species or species group *j*, linking commercial volume to diameter at breast height (*DBH*) and possibly tree height (*H*).
tr	=	1, 2, 3, … TR_p number of trees in plot *p*; dimensionless
XF	=	Plot expansion factor from per plot values to per hectare values
AP	=	plot area; m^2

3. Choose a biomass expansion factor (*BEF*) and a root-shoot ratio (*R*). The *BEF* and root-shoot ratio vary with local environmental conditions, forest type, species and age of trees, and the volume of the commercial component of trees, therefore, they should be calculated for each *LU/LC class*.
These parameters can be determined by either developing a local regression equation or selecting from national inventory, Annex 3A.1 Table 3A.1.10 of GPG LULUCF, or from published sources for specific biomes or forest physiognomies.
If a significant amount of effort is required to develop local *BEFs* and root-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method above (refers to Chapter 4.3 in GPG LULUCF). If that is not possible either, national species specific defaults for *BEF* and *R* can be used. Since both *BEF* and

[77] See for example: Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A primer. FAO Forestry Paper 134, UN FAO, Rome.

143

the root-shoot ratio (*R*) are age or stand density dependent, it is desirable to use age-dependent or stand density-dependent equations (for example, volume per hectare). Stem wood volume can be very small in young stands and *BEF* can be very large, while for old stands *BEF* is usually significantly smaller. Therefore using average *BEF* value may result in significant errors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent or stand density-dependent *BEFs* (but for very young trees, multiplying a small number for stem wood with a large number for the *BEF* can result in significant error).

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

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

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

Where:

$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree *tr*; kg C tree^{-1}
$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree *tr t*; kg C tree^{-1}
V_{tr}	=	Commercial volume of tree *tr*; m^3 tree^{-1}
D_j	=	Wood density for species *j*; tons d. m. m^{-3} (See IPCC GPG-LULUCF, 2003 Table 3A.1.9 or USDA wood density table[78])
BEF_{pl}	=	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree *tr*, in plot *p*; dimensionless.
CF_j	=	Carbon fraction applicable to tree *tr* of species *j*; tons C (tonne d. m.)$^{-1}$.
$R_{j,pl,tr}$	=	Root-shoot ratio, applicable to tree *tr* of species *j* in plot *p*; dimensionless

5. Continue with step 4 of the allometric equation method to calculate the *carbon stock* in above-ground and below-ground biomass by aggregating successively at the tree, plot, and *LU/LC class* levels.

Non-tree component ($Cabnt_{cl}$ and $Cbbnt_{cl}$)

In tropical *forests* non-tree vegetation includes palms, shrubs, herbaceous plants, lianas and other epiphytes. These types of plants are difficult to measure. Unless they form a significant

[78] Reyes *et al.*, 1992. Wood densities of tropical tree species. USDA

144

component of the ecosystem, they should not be measured, which is conservative as their biomass is usually much reduced in the *LU/LC classes* adopted after *deforestation*.

Carbon stock estimations for the non-tree vegetation components are usually based on destructive harvesting, drying and weighting. These methods are described in the Sourcebook for LULUCF projects (Pearson *et al*., 2006) from which most of the following explanations are taken.

For herbaceous plants, a square frame of $1m^2$ made from PVC pipe or another appropriated material is sufficient for sampling. For shrubs and other large non-tree vegetation, larger frames should be used (about 1-2 m^2, depending on the size of the vegetation). For specific *forest* species (e.g. bamboo) or crop types (e.g. coffee) it is also possible to develop allometric equations.

When using destructive sampling, apply the following steps:

a. Place the clip frame at the sampling site. If necessary, open the frame and place around the vegetation.

b. Clip all vegetation within the frame to ground level. Cut everything growing within the quadrate (ground surface not three-dimensional column) and sample this.

c. Weigh the sample and remove a well-mixed sub-sample for determination of dry-to-wet mass ratio. Weight the sub-sample in the field, then oven-dry to constant mass (usually at ~ 70^oC).

d. Calculate the dry mass of each sample. Where a sub-sample was taken for determination of moisture content use the following equation:

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

e. The *carbon stock* in the above-ground non-tree biomass per hectare is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average *carbon stock* per *LU/LC class*, average over all samples:

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

Where:

$Cabnt_{cl}$ = Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

DM_{pl} = Dry mass of sample *pl*; tons of d.m.

XF = Plot expansion factor = [10.000 / Plot Area (m^2)]; dimensionless

CF_{pl} = Carbon fraction of sample *pl*; tons C (tond. m.)$^{-1}$

145

44/12 = Ratio converting C to CO_2-e

pl = 1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless

PL_{cl} = Total number of plots in LU/LC class *cl*; dimensionless

f. The *carbon stock* per hectare of the below-ground non-tree biomass is calculated by multiplying the estimated above-ground estimate by and appropriate root to shoot ratio.

Estimation of *carbon stocks* in the dead wood carbon pool (Cdw_{cl})

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

Deadwood comprises two types: standing dead wood and lying dead wood. Different sampling and estimation procedures are used to estimate the *carbon stocks* of the two components.

$$Cdw_{cl} = Csdw_{cl} + Cldw_{cl} \quad \text{(A3-25)}$$

Where:

Cdw_{cl} = Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

$Csdw_{cl}$ = Average carbon stock per hectare in the standing dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

$Cñdw_{cl}Cdw_{cl}$ = Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

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

Standing dead wood ($Csdw_{cl}$)

a. Within the plots delineated for live trees, the diameter at breast height (*DBH*) of standing dead trees can also be measured. In addition, the standing dead wood is categorized under the following four decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves);
2. Tree with no twig, but with persistent small and large branches;
3. Tree with large branches only;
4. Bole (trunk) only, no branches.

146

b. For classes 2, 3 and 4, the height of the tree (*H*) and the DBH should be measured and the diameter at the top should be estimated. Height can be measured using a clinometer.

c. Top diameter can be estimated using a relascope or through the use of a transparent measuring ruler. Hold the ruler approximately 10-20 cm from your eye and record the apparent diameter of the top of the tree. The true diameter is the equal to:

$$True\ \ diameter-(m)=\frac{Dis\tan ce\ eye\ to\ tree\ (m)}{Dis\tan ce\ eye\ to\ ruler\ (m)}*Ruler\ measurment\ (m) \quad \text{(A3-26)}$$

Distance can also be measured with a laser range finder.

Alternatively, it is conservative to consider the top diameter as zero.

d. For decomposition class 1 the carbon content of each dead tree is estimated using the allometric or *BEF* methods applied for live trees and by subtracting out the biomass of leaves (about 2-3% of the above-ground biomass for hardwood/broadleaf species and 5-6% for softwood/conifer species).

e. For classes 2, 3 and 4, where it is not clear what proportion of the original biomass has been lost, it is conservative to estimate the biomass of just the bole (trunk) of the tree.

The volume can be calculated using the same approach used for live trees. Alternatively, volume can be calculated as the volume of a truncated cone using *DBH* and height measurements and the estimate of the top diameter:

$$Volume\ (m3)=1/3*\pi*H*\left(r_1^2+r_2^2+r_1*r_2\right) \quad \text{(A3-27)}$$

Where:

H	=	Height of the tree; meters
r_1	=	Radius at the base of the tree; meters
r_2	=	Radius at the top of the tree; meters

Alternatively, DBH/2 can be used for the estimation of r_1, which is conservative, since DBH is usually smaller that the diameter at the base of the tree.

The volume is converted to dry biomass using the appropriate wood density D_j and to carbon dioxide equivalents using the carbon fraction CF_j and CO_2/C ratio (44/12), as in the *BEF* method, but ignoring the Biomass Expansion Factor.

f. To aggregate the *carbon stock* of each standing dead tree at the plot level and then at the *LU/LC class* level, continue with step 4 of the allometric equation method.

Lying dead wood (*$Cldw_{cl}$*)

147

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

a. At each plot location, lay out two lines of 50 meters either in a single line or at right angles. The lines should be outside the boundaries of the plot to avoid damage to seedlings in the plots during measurement, and also to biasing the dead wood pool by damaging during tree measurement.

b. Along the length of the lines, measure the diameter of each intersecting piece of coarse dead wood above a predefined minimum diameter (e.g. > 10 cm). Calipers work best for measuring the diameter. A piece of dead wood should only be measured if: (a) more than 50% of the log is above-ground and (b) the sampling line crosses through at least 50% of the diameter of the piece. If the log is hollow at the intersection point, measure the diameter of the hollow: the hollow portion in the volume estimates should be excluded.

c. Assign each piece of dead wood to one of the three following density classes:

   1. Sound
   2. Intermediate
   3. Rotten

   To determine what density class a piece of dead wood fits into, each piece should be struck with a machete. If the blade does not sink into the piece (that is, it bounces off), it is classified as sound. If it sinks partly into the piece and there has been some wood loss, it is classified as intermediate. If the blade sinks into the piece, there is more extensive wood loss and the piece is crumbly, it is classified as rotten.

d. At least 10 random dead wood samples of each three density classes, representing a range of species present, should be collected for density determination. This determination can be accomplished using the maximum moisture content method (Smith 1954), which does not require sample volume determination Using a chainsaw or a handsaw, cut a complete disc or a piece of reasonable size from the selected piece of dead wood and bring to the laboratory for wood density determination.

e. Submerge wood samples in water until saturation is reached. Weight saturated samples. Then, dry samples at 105°C for 26 hours. Extract and weight samples again. Do this last weight quickly, withdrawing samples from oven immediately before weighting them, so that no moisture is absorbed by dried samples before obtaining weights.

f. Calculate the wood density for each density class (sound, intermediate, rotten) from the pieces of dead wood collected. Density is calculated by the following g equation:

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

Where:

148

Dm	=	Deadwood density; g cm^{-3}
Ps	=	Saturated weight of sample; g
Po	=	Anhydrous weight of sample, g
1.53	=	Wood density constant

Average the densities to get a single density value for each class.

g. For each density class, the volume is calculated separately as follows:

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

Where:

$d_1, d_2, ..., d_n$	=	Diameters of intersecting pieces of dead wood; cm
L	=	Length of the line; meters

h. The per hectare *carbon stock* in the lying dead wood carbon pool of each *LU/LC class* is calculated as follows:

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

Where:

$Cldw_{cl}$	=	Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Volume_{dc}$	=	Volume of lying dead wood in the density class *dc*; m^3
D_{dc}	=	Dead wood density of class *dc*; tons d. m. m^{-3}
CF_{dc}	=	Carbon fraction of the density class *dc*; tons C (tonne d. m.)$^{-1}$
44/12	=	Ratio converting C to CO_2e; dimensionless
pl	=	1, 2, 3, … PL_{cl} plots in LU/LC class *cl*; dimensionless
PL_{cl}	=	Total number of plots in LU/LC class *cl*; dimensionless
dc	=	1, 2, 3 dead wood density classes; dimensionless
DC	=	Total number of density classes (3); dimensionless

Estimation of *carbon stocks* in the litter carbon pool (CL_{cl})

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

149

Litter is defines as all dead organic surface material on top of the mineral soil not considered in the lying dead wood pool. Some of this material is recognizable (for example dead leaves, twigs, dead grasses and small branches) and some is unidentifiable (decomposed fragments of different components of originally live biomass. To differentiate small woody debris from the 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.

If litter is measured, it should be sampled at the same time of the year at each monitoring event in order to eliminate seasonal effects. The sampling technique is similar to the one used for non-tree vegetation: a square of 1.0 m^2 made from PVC pipe or another suitable material can be used. The following description of the sampling and data analysis techniques is taken from the Sourcebook for LULUCF projects (Pearson *et al.*, 2006).

a. Place the sampling frame at the sample site.
b. Collect all the litter inside the frame. Pieces of twigs or wood that cross the border of the frame should be cut using a knife or pruning scissors. Place all the litter on a tarpaulin beside the frame or inside a weighting bag.
c. Weigh the sample on-site, then oven-dry to a constant weight.
d. Where sample bulk is excessive, the fresh weight of the total sample should be recorded in the field and a sub-sample of manageable size (approximately 80-100 g) taken for moisture content determination, from which the total dry mass can be calculated.
e. Calculate the dry mass of the sample. Where a sub-sample was taken for determination of the moisture content use equation A3-23 to estimate the dry mass of the whole sample.
f. The *carbon stock* per hectare in the litter carbon pool is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average *carbon stock* per *LU/LC class*, average over all samples (see equation A3-24).

Estimation of *carbon stocks* in soil organic carbon pool ($Csoc_{cl}$)

Methods to estimate *carbon stocks* in the soil organic carbon pool are described in the Sourcebook for LULUCF projects (Pearson *et al.*, 2006) from which the following explanations have been taken.

Three types of variables must be measured to estimate soil organic *carbon stocks*: (1) depth, (2) bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material), and (3) the concentrations of organic carbon within the sample.

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

a. Steadily insert the soil probe to a 30 cm depth. If the soil is compacted, use a rubber mallet to fully insert. If the probe will not penetrate to the full depth, do not force it as

150

it is likely a stone or root that is blocking its route and, if forced, the probe will be damaged. Instead, withdraw the probe, clean out any collected soil and insert in a new location.

b. Carefully extract the probe and place the sample into a bag. Because the carbon concentration of organic materials is much higher than that of the mineral soil, including even a small amount of surface material can result in a serious overestimation of soil *carbon stocks*.

c. To reduce variability, aggregate four samples from each collection point for carbon concentration analysis.

d. At each sampling point, take two additional aggregated cores for determination of bulk density. When taking the cores for measurements of bulk density, care should be taken to avoid any loss of soil from the cores.

e. Soil samples can be sent to a professional laboratory for analysis. Commercial laboratories exist throughout the world and routinely analyze plant and soil samples using standard techniques. It is recommended the selected laboratory be checked to ensure they follow commonly accepted standard procedures with respect to sample preparation (for example, mixing and sieving), drying temperatures, and carbon analysis methods.

For bulk density determination, ensure the laboratory dries the samples in an oven at 105°C for a minimum of 48 hours. If the soil contains coarse, rocky fragments, the coarse fragments must be retained and weighted. For soil carbon determination, the material is sieved through a 2 mm sieve, and then thoroughly mixed. The well-mixed sample should not be oven-dried for the carbon analysis, but only air-dried; however, the carbon concentration does need to be expressed on an oven dry basis at 105 °C. The dry combustions method using o controlled temperature furnace (for example, a LECO CHN-2000 or equivalent) is the recommended method for determining total soil carbon, but the Walkley-Black method is also commonly used.

f. Calculate the bulk density of the mineral soil core:

$$Bulk\ density\ (g/cm^3) = \frac{oven\ dry\ mass\ (g/cm^3)}{core\ volume\ (cm^3) - \dfrac{mass\ of\ coarse\ fragments\ (cg)}{density\ of\ rock\ fragments\ (cg/m^3)}} \quad \text{(A3-31)}$$

Where the bulk density is for the < 2 mm fraction, coarse fragments are > 2 mm. The density of rock fragments is often given as 2.65 g/cm^3.

g. Using the carbon concentration data obtained from the laboratory, the amount of carbon per unit area is given by:

$$Csoc_{cll}\ (t/ha) = [(soil\ bulk\ density\ (g/cm^3) * soil\ depth\ (cm) * C)] * 100 \quad \text{(A3-32)}$$

In the above equation, C must be expressed as a decimal fraction. For example, 2.2% carbon is expressed as 0.022 in the equation.

151

h. The *carbon stock* per hectare in the soil organic carbon pool is calculated by averaging the *carbon stock* estimates per each *LU/LC class*:

$$Csoc_{cl} = \frac{\sum_{pl=1}^{PL_{pl}} Csoc_{pl}}{PL_{pl}} \qquad \text{(A3-33)}$$

Where:

$Csoc_{cl}$	=	Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Csoc_{pl}$	=	*Carbon stock* per hectare in the soil organic carbon pool estimated for the plot *pl*; tCO_2-e ha^{-1}
pl	=	1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless
PL_{pl}	=	Total number of plots in LU/LC class *cl*; dimensionless

Estimation of *carbon stocks* in the harvested wood products carbon pool (Cwp_{cl})

The wood products carbon pool must be included if there is timber harvest in the *baseline* case prior to or in the process of *deforestation* and the wood products carbon pool is determined to be significant. In this case, Cwp_{cl} must be subtracted in the calculation of $Ctot_{cl}$ in the *baseline* case and can be added in the calculation of $Ctot_{cl}$ in the project case.

Carbon stocks in wood products are those stocks remaining in wood products after 100 years; the bulk of emissions associated with timber harvest, processing and waste, and eventual product retirement occur within this timeframe, and calculations employ the simplifying assumption that the proportion remaining after 100 years is effectively "permanent."

Accounting for carbon stocks in wood products in the *baseline* case should only take place at the time of *deforestation* (year *t*). In the project case, Cwp_{cl} can be accounted at the years of planned timber harvest, in which case monitoring is mandatory.

This module follows the conceptual framework detailed in Winjum *et al.* 1998[79], applying the simplifying (and conservative) assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al.* 1998.

If approved timber harvest plans, specifying harvest intensity per forest class in terms of volume extracted per ha, are available for the *project area* use Method 1. If approved harvest plans are not available use Method 2.

Method 1: Direct Volume Extraction Estimation

[79] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

152

Step 1: Calculate the biomass carbon of the commercial volume extracted since the project start date and in the process of *deforestation* as follows:

$$CXB_{w,icl,t} = \frac{1}{ABSLPA_{icl,t}} * (\sum_{t=1}^{t*} \sum_{j=1}^{J} (VEX_{w,j,icl,t} * D_j * CF_j * \frac{44}{12}) \qquad \text{(A3-34)}$$

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*; tCO_2-e ha^{-1}
icl	=	1, 2, 3, …*Icl* 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**	=	the year at 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^{-1}d.m.
44/12	=	Ratio of molecular weight of carbon to CO_2; dimensionless

Step 2: Calculate the proportion of biomass carbon extracted at time *t* that remains sequestered in long-term wood products after 100 years.

$$Cwp_{icl,t} = \sum_{w=1}^{W} CXB_{w,icl,t} * (1 - WW_w) * (1 - SLF_w) * (1 - OF_w) \qquad \text{(A3-35)}$$

Where:

$Cwp_{icl,t}$	=	Carbon stock in the wood products carbon pool (stock remaining in wood products after 100 years) in forest class *icl* at time *t*; tCO_2-e ha^{-1}
icl	=	1, 2, 3, …*Icl* 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

153

$CXB_{w,icl,t}$	=	Mean stock of extracted biomass carbon by class of wood product *w* from forest class *icl* at time *t*; tCO_2-e ha^{-1}
WW_w	=	Wood waste for wood product class *w*. The fraction immediately emitted through mill inefficiency; dimensionless
SLF_w	=	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless
OF_w	=	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless

Method 2: Commercial inventory estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of *deforestation*:

$$CXB_{icl,t} = Cab_{iicl,t} * \frac{1}{BCEF} * Pcom_{icl} \qquad \text{(A3-36)}$$

Where:

$CXB_{icl,t}$	=	Mean stock of extracted biomass carbon from forest class *icl* at time *t*; tCO_2-e ha^{-1}
$Cab_{icl,t}$	=	Mean above-ground biomass carbon stock in forest class *icl* at time *t*; tCO_2-e ha^{-1}
$BCEF$	=	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass; dimensionless
$Pcom_{icl}$	=	Commercial volume as a percent of total aboveground volume in *forest class icl*; dimensionless
t	=	1, 2, 3 … *T* years, a year of the project crediting period; dimensionless
icl	=	1, 2, 3… *icl* pre-*deforestation* forest classes; dimensionless

Step 2: Identify the wood product class(es) (*w*, defined here as sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in Step 1. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

Step 3: Calculate the proportion of biomass carbon extracted at time *t* that remains sequestered in long-term wood products after 100 years. This module applies the simplifying

154

(and conservative) assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al*. 1998.

$$Cwp_{icl,t} = \sum_{w=1}^{W} CXB_{w,icl,t} * (1 - WW_w) * (1 - SLF_w) * (1 - OF_w) \qquad \text{(A3-37)}$$

Where:

$Cwp_{icl,t}$	=	Carbon stock in wood products pool (stock remaining in wood products after 100 years) in forest class *icl* at time *t*; tCO_2-e ha^{-1}
icl	=	1, 2, 3 … *icl* 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 forest class *icl* at time *t*; tCO_2-e ha^{-1}
WW_w	=	Wood waste for wood product class *w*. The fraction immediately emitted through mill inefficiency; dimensionless
SLF_w	=	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless
OF_w	=	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless

155

APPENDIX 4
METHODS TO ESTIMATE EMISSIONS FROM ENTERIC FERMENTATION AND MANURE MANAGEMENT

Estimation of CH_4 emissions from enteric fermentation ($ECH4ferm_{,t}$)

The amount of methane[80] emitted by a population of animals is calculated by multiplying the emission rate per animal by the number of animals. 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 PCC GPG 2000 and IPCC 2006 Guidelines for AFOLU, use the following equation[81]:

$$ECH4ferm_t = EF_1 * Population_t * 0{,}001 * GWP_{CH4} \quad \text{(A4-1)}$$

$$Population_t = Pforage_t / (DBI * 365) \quad \text{(A4-2)}$$

Where:

$ECH4ferm_t$	CH_4 emissions from enteric fermentation at year *t*; tCO_2e
EF_1	Enteric CH_4 emission factor for the livestock group; kg CH_4 head^{-1} yr^{-1}
$Population_t$	Equivalent number of forage-fed livestock at year *t*; heads
$Pforage_{t}$,*t*	Production of forage at year *t*; kg d. m. yr^{-1}
DBI	Daily biomass intake; kg d.m. head^{-1} day^{-1}
GWP_{CH4}	Global warming potential for CH_4 (with a value of 21 for the first commitment period); dimensionless
0.001	Conversion factor of kilograms into tons; dimensionless
365	Number of day per year; dimensionless
t	1, 2, 3, … *T* years of the project crediting period

80 Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce CH_4, although ruminants are the largest source since they are able to digest cellulose, due to the presence of specific micro organisms in their digestive tracts. The amount of CH_4 that is released depends on the type, age, and weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal.

81 Refer to equation 10.19 and equation 10.20 in IPCC 2006 GL AFOLU or equation 4.12 and equation 4.13 in GPG 2000 for agriculture.

156

The production of forage can be estimated by collecting production rates from the literature that represents the shrub species, climate, soil conditions and other features of the areas in which forage will be produced. Sampling surveys are also a good option.

Country-specific emission factors for enteric CH_4 emissions are documented in peer reviewed literature or can be obtained from national GHG inventories. Default values are given in Table 10.10 and 10.11 in the IPCC 2006 Guidelines for AFOLU. When selecting emission factors it is important to select those from a region that is similar to the *project area*. The tables in Annex 10A.1 of the IPCC 2006 Guidelines for AFOLU specify the animal characteristic such as weight, growth rate and milk production used to estimate the emission factors. These tables should be consulted in order to ensure that the local conditions are similar. In particular, data on average milk production by dairy livestock should be analyzed when selecting an emission factor for dairy livestock. To estimate the emission factor, the data in Table 10 A.1 can be interpolated using the data on the local average milk production.

For data on daily biomass intake use local data or data that are applicable to the local conditions according to peer-reviewed literature or the national GHG inventory. When selecting a value for daily biomass intake, ensure that the chosen data are applicable to both the forage types to be produced and the livestock group (see also Table 5 in Appendix 2).

Estimation of CH_4 emissions from manure management ($ECH4man_t$)[82]

The storage and treatment of manure under anaerobic conditions produces CH_4. These conditions occur most readily when large numbers of animals are managed in confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid -based systems. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of manure that decomposes 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 can produce a significant quantity of CH_4. The temperature and the retention time of storage greatly affect the amount of methane produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.

CH_4 emissions from manure management for the forage-fed livestock can be estimated using IPCC methods[83].

$$ECH4man_t = EF_2 * Population_t * 0{,}001 * GWP_{CH4} \qquad \text{(A4-3)}$$

[82] Taken from AR-AM0006 version 1

[83] Refer to equation 10.22 in AFOLU volume of the IPCC 2066 Guidelines or equation 4.15 in GPG 2000 for agriculture.

157

Where:

$ECH4man_{t,t}$	CH_4 emissions from manure management at year *t*; tCO_2e
EF_2	Manure management CH_4 emission factor for the livestock group; kg CH_4 $head^{-1}$ yr^{-1}
$Population_t$	Equivalent number of forage-fed livestock at year *t*; heads
GWP_{CH4}	Global warming potential for CH_4 (with a value of 21 for the first commitment period); dimensionless
0.001	Conversion factor of kilograms into tons; dimensionless
t	= 1, 2, 3 … *T* years of the project crediting period

The best estimate of emissions will usually be obtained using country-specific emission factors that have been published in peer-reviewed literature or in the national GHG inventory. It is recommended that country-specific emission factors be used that reflect the actual duration of storage and type of treatment of animal manure in the management system used. If appropriate country-specific emission factors are unavailable, default emission factors presented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU may be used. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the *project area*.

Estimation of N_2O emissions from manure management ($E_{l,N2O,manure}$) [84]

Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. The N_2O emissions from manure management can be estimated using method provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000[85]

$$EN2Oman_t = EdirN2Oman_t + EindN2Oman_t \quad \text{(A4-4)}$$

$$EdirN2Oman_t = Population_t * Nex * EF_3 \cdot 0{,}001 * 44/28 * GWP_{N20} \quad \text{(A4-5)}$$

$$EindN2Oman_t = Population_t * Nex * Frac_{gas} * EF_4 * 0{,}001 * 44/28 * GWP_{N2O} \quad \text{(A4-6)}$$

[84] Adapted from AR-AM0006 version 1.

[85] 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.

158

Where:

$EN2Oman_{fcl,t}$	N_2O emissions from manure management at year t; tCO_2e[1]
$EdirN_2Oman_t$	Direct N_2O emissions from manure management at year t; tCO_2e
$EindNOman_{t,t}$	Indirect N_2O emissions from manure management at year t; tCO_2e
$Population_{,t}$	Equivalent number of forage-fed livestock at year t; heads
Nex	Annual average N excretion per livestock head; kg N $head^{-1}$ yr^{-1}
EF_3	Emission factor for N_2O emissions from manure management for the livestock group; kg N_2O-N (kg N^{-1})
EF_4	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces; kg N_2O-N (kg NH_3-N and NO_x-N emitted)$^{-1}$. Use of 0.01 IPCC default factor is recommended. Note: The use of the IPCC default factor 0.01 is recommended.
$Frac_{gas}$	Fraction of managed livestock manure nitrogen that volatilizes as NH3 and NOx in the manure management phase; kg NH_3-N and NO_x-N emitted (Kg N)$^{-1}$
GWP_{N2O}	Global warming potential for N_2O (310 for the first commitment period); dimensionless
44/28	Conversion of N_20-N emissions to N_2O emissions;
0.001	Conversion factor of kilograms into tons; dimensionless

The best estimate of the annual nitrogen excretion rates for each livestock group will usually be obtained using country-specific rates from published peer reviewed literature or from the national GHG inventory. If country-specific data cannot be collected or derived, or appropriate data are not available from another country with similar conditions, default nitrogen excretion rates can be obtained from table 10.19 of IPCC 2006 Guidelines for AFOLU.

The possible data sources for emission factors are similar. Default emission factors are given in table 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU and default values for volatilization of NH_3 and NO_x ($Frac_{gas}$) in the manure management system are presented in table 10.22 of the same IPCC 2006 Guidelines. For EF_4 the IPCC default value 0.01 is recommended (equation 10.27, IPCC 2006 Guidelines for AFOLU).

159

APPENDIX 5
DATA AND PARAMETERS USED IN THIS METHODOLOGY

Notation	Description	Unit	Equation	Observation	Source	Monitoring
A	Area of error due to observed change predicted as persistence	ha			measured or estimated from literature	each renewal of fixed baseline period
$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum	ha	4, 9		calculated	each renewal of fixed baseline period
$ABSLPA_{ct,t}$	Area of category *ct* deforested at time *t* within the project area in the baseline case	ha	15		measured or estimated from literature	each renewal of fixed baseline period
$ABSLPAf_{cl,t}$	Area of final (post-deforestation) non-forest class f*cl* deforested at time *t* within the *project area* in the *baseline* case	ha	14		calculated	each renewal of fixed baseline period
$ABSLPAi_{cl,t}$	Area of initial (pre-deforestation) forest class i*cl* deforested at time *t* within the *project area* in the *baseline* case	ha	14		calculated	each renewal of fixed baseline period
$ABSLPA_{t,i}$	Annual area of *baseline deforestation* in stratum *i* within the *project area* at a year *t*;	ha	12		calculated	each renewal of fixed baseline period
$ABSLRR_{i,t}$	Annual area of *baseline deforestation* in stratum *i* within the *reference region* at a year *t*	ha	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		calculated	each renewal of fixed baseline period
$Aoptimal_i$	Area of "optimal" forest land suitable for conversion to non-forest land within stratum *i*	ha	3, 7		calculated	each renewal of fixed baseline period

AP	Plot area	m2	A3-13		measured or estimated from literature	only once at project start and when mandatory
$APDPA_{icl,t}$	Areas of planned deforestation in forest class *icl* at year *t* in the *project area*	ha		*ex ante* and *ex post*	measured or estimated from literature	annually
$APFPA_{icl,t}$	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
$ARRhrp_i$	Total area deforested during the historical reference period in the reference region	ha	2		measured or estimated from literature	each renewal of fixed baseline period
ARR_i	Total forest area in stratum *i* within the *reference region* at the project start date	ha	6, 11		measured or estimated from literature	each renewal of fixed baseline period
$Asub\text{-}optimal_i$	Area of "sub-optimal" forest land suitable for conversion to non-forest land within stratum *i*;	ha	5		calculated	each renewal of fixed baseline period
B	Area of correct due to observed change	ha	13		measured or estimated from literature	each renewal of fixed baseline period

161

	predicted as change					
BCEF	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass	dimensionless	A3-9, A3-36		measured or estimated from literature	only once at project start
BEF_{pl}	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree *tr*, in plot *pl*	dimensionless	A3-21		measured or estimated from literature	only once at project start
C	Area of error due to observed change predicted as wrong gaining category	ha	13		measured or estimated from literature	each renewal of fixed baseline period
Cab_{cl}	Average carbon stock per hectare in the above-ground biomass carbon pool of LU/LC class *cl*	t CO_2e ha^{-1}	A3-6, A3-14,A3-36		measured or estimated from literature	only once at project start and when mandatory
$Cabnt_{cl}$	Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of LU/LC class *cl*	t CO_2e ha^{-1}	A3-7, A3-24		measured or estimated from literature	only once at project start and when mandatory
$Cabt_{cl}$	Average carbon stock per hectare in the above-ground tree biomass carbon pool of LU/LC class *cl*	t CO_2e ha^{-1}	A3-7		measured or estimated from literature	only once at project start and when mandatory
Cbb_{cl}	Average carbon stock per hectare below-ground biomass carbon	t CO_2e ha^{-1}	A3-6, A3-17		measured or estimated from literature	only once at project start and when mandatory

162

	pool of LU/LC class cl					
$Cbbnt_{cl}$	Average carbon stock per hectare below-ground non-tree biomass carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
$Cbbt_{cl}$	Average carbon stock per hectare below-ground tree biomass carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
Cdw_{cl}	Average carbon stock per hectare in the in the dead wood biomass carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-6, A3-25		measured or estimated from literature	only once at project start and when mandatory
$CE_{,l,p}$	Average combustion efficiency of the carbon pool *p* in the *forest class*	dimensionless	19		measured or estimated from literature	only once at project start
CF_{dc}	Carbon fraction of the density class *dc*	tons C (tonne d. m.)$^{-1}$	A3-30		measured or estimated from literature	only once at project start and when mandatory
CF_j	Carbon fraction for tree *tr*, of species, group of species or forest type *j*	tons C (tonne d. m.)$^{-1}$	A3-11, A3-21, A3-24		measured or estimated from literature	only once at project start
CF_{pl}	Carbon fraction of sample *pl*	tons C (tonne d. m.)$^{-1}$	A3-24		calculated	only once at project start and when mandatory
cl	1, 2, 3 … *Cl* LU/LC classes	dimensionless	A3-3		measured or estimated from literature	each renewal of fixed baseline period
Cl_{cl}	Average carbon stock per hectare in the litter carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-6		measured or estimated from literature	only once at project start and when mandatory
$Cldw_{cl}$	Average *carbon stock* per hectare in the lying dead wood carbon	tCO_2-e	A3-25, A3-30		measured or estimated from literature	only once at project start and when mandatory

163

	pool of the *LU/LC class cl*					
$C_{p,icl}$	Average *carbon stock* per hectare in the carbon pool *p* burnt in the *forest class icl*;	tCO_2-e ha^{-1}	19		calculated	only once at project start
$Csdw_{cl}$	Average *carbon stock* per hectare in the standing dead wood carbon pool of the *LU/LC class cl*	tCO_2-e	A3-25		measured or estimated from literature	only once at project start and when mandatory
$Csoc_{cl}$	Average carbon stock per hectare in the soil organic carbon pool of LU/LC class cl	t CO_2e ha^{-1}	A3-6, A3-33		measured or estimated from literature	only once at project start and when mandatory
$Csoc_{pl}$	*Carbon stock* per hectare in the soil organic carbon pool estimated for the plot *pl*;	tCO_2-e ha^{-1}	A3-33		measured or estimated from literature	only once at project start
ct	1, 2, 3 … *CT* categories of LU/LC change	dimensionless	15		calculated	each renewal of fixed baseline period
$Ctot_{cl}$	Average carbon stock per hectare in all accounted carbon pools of LU/LC class cl	t CO_2e ha^{-1}	A3-6		calculated	only once at project start and when mandatory
$Ctot_{icl,t}$	Average carbon stock of all accounted carbon pools in forest class i*cl* at time *t*	tCO_2-e ha^{-1}	14		calculated	only once at project start and when mandatory
Cwp_{cl}	Average carbon stock per hectare in the harvested wood products carbon pool (stock remaining in wood products after 100 years) of LU/LC class cl	t CO_2e ha^{-1}	A3-6, A3-35, A3-37		measured or estimated from literature	only once at project start and when mandatory

164

$CXB_{fcl,t}$	Mean stock of extracted biomass carbon from *forest class fcl* at time *t*	tCO_2-e ha^{-1}	A3-35, A3-37		measured or estimated from literature	only once at project start and when mandatory
$CXB_{w,fcl,t}$	Mean stock per hectare of extracted biomass carbon by class of wood product *w* from *forest class fcl* at time *t*	tCO_2-e ha^{-1}	A3-34, A3-35		measured or estimated from literature	only once at project start and when mandatory
D	Area of error due to observed persistence predicted as change	ha			measured or estimated from literature	each renewal of fixed baseline period
$d1, d2, ..., dn$	Diameters of intersecting pieces of dead wood	cm	A3-29		measured or estimated from literature	only once at project start and when mandatory
DBH	Diameter at Breast Height	cm			measured or estimated from literature	only once at project start and when mandatory
DBI	Daily biomass intake	kg d.m. $head^{-1}$ day^{-1}	A5-2		measured or estimated from literature	each renewal of fixed baseline period
dc	1, 2, 3 dead wood density classes	dimensionless	A3-30		defined	
DC	Total number of density classes (3)	dimensionless	A3-30		defined	
ΔCab_{ct}	Average *carbon stock change factor* in the below-ground biomass carbon pool of category *ct*	t CO_2e ha^{-1}			calculated	only once at project start and when mandatory
ΔCbb_{ct}	Average *carbon stock change factor* in the below-ground biomass carbon pool of category ct	t CO_2e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CBSLPA_t$	Total baseline carbon stock change within the project area	tCO_2-e	14		calculated	each renewal of fixed baseline period

165

	at year *t*					
ΔCdw_{ct}	Average *carbon stock change factor* in the dead wood biomass carbon pool of category ct	t CO_2e ha^{-1}			calculated	only once at project start and when mandatory
ΔCl_{ct}	Average *carbon stock change factor*in the litter carbon pool of category ct	t CO_2e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CPAdPA_t$	Total decrease in carbon stock due to all planned activities at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPAiPA_t$	Total increase in carbon stock due to all planned activities at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPDdPA_t$	Total decrease in carbon stock due to planned deforestation at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPDdPA_t$	Total decrease in carbon stock due to planned deforestation at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPFdPA_t$	Total decrease in carbon stock due to planned fuel-wood and charcoal activities at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPFiPA_t$	Total increase in carbon stock due to planned fuel-wood and charcoal	tCO_2-e		*ex ante* and *ex post*	calculated	annually

166

	activities at year t in the project area					
$\Delta CPLdPA_t$	Total decrease in carbon stock due to planned logging activities at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPLiPA_t$	Total increase in carbon stock due to planned logging activities at year t in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPNiPA_t$	Total increase in carbon stock due to planned protection of growing forest classes in the project area at year t	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta CPSPA_t$	Total project carbon stock change within the project area at year t	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$\Delta Csoc_{ct}$	Average *carbon stock change factor* in the soil organic carbon pool of category ct	$t\ CO_2e\ ha^{-1}$			calculated	only once at project start and when mandatory
$\Delta Ctot_{ct}$	Average *carbon stock change factor* in all accounted carbon pools of category ct	$t\ CO_2e\ ha^{-1}$			calculated	only once at project start and when mandatory
$\Delta Ctot_{ct,t}$	Carbon stock change factor (also called emission factor) for all accounted carbon pools in category *ct* at time *t*	tCO_2-e ha^{-1}	15		calculated	only once at project start and when mandatory

167

$\Delta CUDdPA_t$	Total *ex ante* actual carbon stock change due to unavoided unplanned deforestation at year *t* in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
ΔCwp_{ct}	Average *carbon stock change factor* in the harvested wood products carbon pool (stock remaining in wood products after 100 years) of category ct	t CO_2e ha^{-1}			calculated	only once at project start and when mandatory
D_{dc}	Dead wood density of class *dc*	tons d. m. m^{-3}	A3-30		measured or estimated from literature	only once at project start and when mandatory
$DFRR_i$	Discount factor applicable to stratum *i*	ha yr^{-1}	2		calculated	each renewal of fixed baseline period
D_j	Mean wood density of species *j*	t d.m.m^{-3}	A3-34		measured or estimated from literature	only once at project start
DLF	Displacement Leakage Factor	%			defined	each renewal of fixed baseline period
Dm	Deadwood density	g cm^{-3}	A3-28		measured or estimated from literature	only once at project start and when mandatory
DM_{pl}	Dry mass of sample *pl*;	tons of d.m.	A3-24		measured or estimated from literature	only once at project start and when mandatory
$EBBBSLPA_t$	Annual total baseline non-CO_2 emissions from forest fires at year *t* in the project area	tCO_2-e			calculated	annually
$EBBBSPA_t$	Total baseline non-CO_2 emissions from forest fire at year *t* in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
$EBBCH4_{icl}$	CH_4 emission from biomass burning in forest	tCO_2-e	16, 18	*ex ante* and *ex post*	calculated	annually

168

	class *icl*					
EBBCO2$_{icl}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class *icl*;	$tCO_2e\ ha^{-1}$	17, 18, 19		calculated	only once at project start
EBBN2O$_{icl}$	N_2O emission from biomass burning in forest class *icl*	tCO_2-e	16, 17	*ex ante* and *ex post*	calculated	annually
EBBPSPA$_t$	Total *ex ante* actual non-CO_2 emissions from forest fire due to unavoided unplanned deforestation at year *t* in the project area	tCO_2-e		*ex ante* and *ex post*	calculated	annually
EBBtot$_{icl}$	Total GHG emission from biomass burning in forest class *icl*	tCO_2-e	16	*ex ante* and *ex post*	calculated	annually
ECH4ferm$_t$	CH_4 emissions from enteric fermentation at year *t*	tCO_2-e	A5-1		calculated	annually
ECH4man$_t$	CH_4 emissions from manure management at year *t*	tCO_2-e	A5-3		calculated	annually
$EdirN_2Oman_t$	Direct N_2O emissions from manure management at year *t*	tCO_2-e	A5-4, A5-5		calculated	annually
EF_1	Enteric CH_4 *emission factor* for the livestock group	kg CH_4 head^{-1} yr^{-1}	A5-1		calculated	each renewal of fixed baseline period
EF1	Emission Factor for emissions from N inputs	$tN_2O\ tN^{-1}$			measured or estimated from literature	each renewal of fixed baseline period
EF_2	Manure management CH_4 *emission factor* for the livestock group	kg CH4 head^{-1} yr^{-1}	A5-3		measured or estimated from literature	each renewal of fixed baseline period

169

EF_3	*Emission factor* for N_2O emissions from manure management for the livestock group	kg N_2O-N (kg N^{-1}) $head^{-1}$ yr^{-1}	A5-5		measured or estimated from literature	each renewal of fixed baseline period
EF_4	*Emission factor* for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces	kg N_2O-N (kg NH_3-N and NO_x-N emitted)$^{-1}$ $head^{-1}$ yr^{-1}	A5-6		measured or estimated from literature	each renewal of fixed baseline period
$EgLK_t$	Emissions from grazing animals in leakage management areas at year *t*	tCO_2-e	23		calculated	annually
EI	*Ex ante* estimated Effectiveness Index	%			defined	annually
$EindNOman_t$	Indirect N_2O emissions from manure management at year *t*	tCO_2-e	A5-4, A5-5		calculated	annually
$EN2Oman_t$	N_2O emissions from manure management at year *t*	tCO_2-e	A5-4		calculated	annually
$EN2Oman_t$	N_2O emissions from manure management at year *t*	tCO_2-e	A5-4		calculated	annually
ER_{CH4}	Emission ratio for CH_4 (IPCC default value = 0.012)	dimensionless	18		defined	each renewal of fixed baseline period
ER_{N2O}	Emission ratio for N_2O (IPCC default value = 0.007)	dimensionless	17		defined	each renewal of fixed baseline period
$Fburnt_{icl}$	Proportion of *forest* area burned during the *historical reference period* in the *forest class icl*;	%	19		measured or estimated from literature	only once at project start

170

fcl	1, 2, 3 … *Fcl* final (post-deforestation) non-forest classes	dimensionless	14		measured or estimated from literature	each renewal of fixed baseline period
$f_j(DBH,H)_{ab}$	an allometric equation for species, or group of species, or forest type *j*, linking above-ground tree biomass (in kg $tree^{-1}$ – see the note above) to diameter at breast height (*DBH*) and possibly tree height (*H*).		A3-10		measured or estimated from literature	only once at project start
$f_j(DBH,H)_V$	A commercial volume equation for species or species group *j*, linking commercial volume to diameter at breast height (*DBH*) and possibly tree height (*H*).		A3-16		measured or estimated from literature	only once at project start
FOM	"Figure of Merit"	dimensionless	13	This is measure of goodness of fit between observed and predicted deforestation	calculated	each renewal of fixed baseline period
FON_t	Mass of organic fertilizer nitrogen applied at year *t* adjusted for volatilization as NH_3 and NOx	tN			calculated	annually
$Frac_{gas}$	Fraction of managed livestock manure nitrogen that volatilizes as NH3 and	kg NH_3-N and NO_x-N emitted $(Kg\ N)^{-1}$	A5-6		measured or estimated from literature	each renewal of fixed baseline period

171

	NOx in the manure management phase					
FracGASF	Fraction that volatises as NH_3 and NO_x for synthetic fertilizers	dimensionless			measured or estimated from literature	each renewal of fixed baseline period
FracGASM	Fraction that volatises as NH_3 and NO_x for organic fertilizers	dimensionless			measured or estimated from literature	each renewal of fixed baseline period
FSN_t	Mass of synthetic fertilizer nitrogen applied at year *t* adjusted for volatilization as NH_3 and NOx	tN			calculated	annually
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period)	dimensionless	18		defined	each renewal of fixed baseline period
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)	dimensionless	17		defined	each renewal of fixed baseline period
H	Height of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
i	1, 2, 3 .. I_{RR} A stratum within the *reference region*	dimensionless	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12		defined	each renewal of fixed baseline period
i	number of syntetic fertilizer types	dimensionless			defined	annually
icl	1, 2, 3 … *Icl* initial (pre-deforestation) forest classes	dimensionless	14		measured or estimated from literature	each renewal of fixed baseline period
j	number of organic fertilizer	dimensionless			defined	annually

172

	types					
L	Length of the line	m	A3-29		measured or estimated from literature	only once at project start and when mandatory
$MSFi_t$	Mass of synthetic fertilizer type *i* applied at year *t*	t			calculated ex ante, measured ex post	annually
$MSFj_t$	Mass of organic fertilizer type *j* applied at year *t*	t			calculated ex ante, measured ex post	annually
$NCOF_j$	Nitrogen content of organic fertilizer type *j* applied	gN per 100g fertilizer			measured or estimated from literature	annually
NCR	Nitrogen/Carbon ratio (IPCC default value = 0.01)	dimensionless	17		defined	each renewal of fixed baseline period
$NCSF_i$	Nitrogen content of synthetic fertilizer type *i* applied	gN per 100g fertilizer			measured or estimated from literature	annually
Nex	Annual average N excretion per livestock head	kg N $head^{-1}$ yr^{-1}	A5-6		measured or estimated from literature	each renewal of fixed baseline period
OF_w	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
p	Carbon pool that could burn (above-ground biomass, dead wood, litter)	dimensionless	19		defined	each renewal of fixed baseline period
$Pburnt_{p,icl}$	Average proportion of mass burnt in the carbon pool *p* in the *forest class icl*;	%	19		measured or estimated from literature	only once at project start
$PCab_{pl}$	*Carbon stock* in above-ground biomass in plot *pl*	tC ha^{-1}	A3-13		calculated	only once at project start and when mandatory
$PCab_{pl}$	*Carbon stock* in above-ground	tC ha^{-1}	A3-14		calculated	only once at project start and when

173

	biomass in plot *pl*					mandatory
$Pcom_{fcl}$	Commercial volume as a percent of total aboveground volume in *forest class fcl*	dimensionless	A3-36		measured or estimated from literature	only once at project start and when mandatory
PCx_i	Average *in situ* Production Costs for one ton of product P*x* in stratum *i*	\$/t	1	This variable may have different values within different strata of the reference region	measured or estimated from literature	each renewal of fixed baseline period
$Pforage_t$	Production of forage at year *t*	kg d. m. yr^{-1}	A5-2		calculated ex ante, measured ex post	each renewal of fixed baseline period
pl	1, 2, 3, … PL_{cl} plots in *LU/LC class* cl	dimensionless	A3-14, A3-17, A3-24, A3-33		calculated	only once at project start and when mandatory
PL_{cl}	Total number of plots in *LU/LC class* cl	dimensionless	A3-14, A3-17, A3-24, A3-34		calculated	only once at project start and when mandatory
Po	Anhydrous weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
$Population_t$	Equivalent number of forage-fed livestock at year *t*	number of heads	A5-1		calculated ex ante, measured ex post	annually
$PPA_{i,t}$	Proportion of stratum *i* that is within the *project area* at time *t*	%	12		calculated	each renewal of fixed baseline period
PPx_l	Potential profitability of product *Px* at the location *l*	\$/t	1		calculated	each renewal of fixed baseline period
Ps	Saturated weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
Px	Product x produced in the reference region	dimensionless	1		measured or estimated from literature	each renewal of fixed baseline period
r_1	Radius at the base of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory

174

r_2	Radius at the top of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
$RBSLRR_{i,t}$	Percentage of remaining *forest* area at year *t* - 1 in stratum *i* to be deforested at year *t*	%	11	Used as an alaternative to $ABSLRR_{i,t}$ in baseline approach "c"	calculated	each renewal of fixed baseline period
R_j	Root-shoot ratio appropriate for species, group of species or forest type	dimensionless	A3-18		measured or estimated from literature	only once at project start
$R_{j,pl,tr}$	Root-shoot ratio, applicable to tree *tr* of species *j* in plot *pl*	dimensionless	A3-22		measured or estimated from literature	only once at project start
S$x	Selling Price of product *Px*	$/t	1		measured or estimated from literature	each renewal of fixed baseline period
SLF_w	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
SPx_l	Selling Point *l* of product *Px*	map	1		measured or estimated from literature	each renewal of fixed baseline period
t	1, 2, 3 … *T* a year of the proposed *crediting period*	dimensionless	almost all equations		defined	
*t**	the year at which the area $ABSLPA_{fcl,t}$ is deforested in the baseline case	dimensionless	A3-34		defined	
$Taverage_i$	Number of years in which $Aaverage_i$ is deforested in the baseline case	yr	4		calculated	each renewal of fixed baseline period
$taverage_i$	Year at which $Taverage_i$ ends	yr	9		calculated	each renewal of fixed baseline period
$TBab_j$	above-ground biomass of a tree of species, or species	kg $tree^{-1}$ or t $tree^{-1}$	A3-10		calculated	only once at project start

175

	group, or forest type *j*					
$TBab_{tr}$	Above-ground biomass of tree *tr*	kg $tree^{-1}$ or t $tree^{-1}$	A3-11, A3-13, A3-21		calculated	only once at project start
$TCab_{tr}$	*Carbon stock* in above-ground biomass of tree *tr*	kg C $tree^{-1}$ or t C $tree^{-1}$	A3-11, A3-21		calculated	only once at project start
$TCbb_{tr}$	*Carbon stock* in below-ground biomass of tree *tr*	kg C $tree^{-1}$	A3-16, A3-22		calculated	only once at project start and when mandatory
TCv	Average Transport Cost per kilometer for one ton of product *Px* on land, river or road of type *v*	$/t/km	1		measured or estimated from literature	each renewal of fixed baseline period
TDv	Transport Distance on land, river or road of type *v*	$/t/km	1		calculated	each renewal of fixed baseline period
Thrp	Duration of the historical reference period in years	yr	2		defined	only once at project start
$Toptimal_i$	Number of years since the start of the REDD project activity in which *Aoptimal* in stratum *i* is deforested in the baseline case	yr	3		calculated	each renewal of fixed baseline period
$toptimal_i$	Year at which $Toptimal_i$ ends	yr	7, 8, 9		calculated	each renewal of fixed baseline period
tr	1, 2, 3, … TR_{pl} number of trees in plot *pl*	dimensionless	A3-13		measured or estimated from literature	only once at project start and when mandatory
$Tsub\text{-}optimal_i$	Number of years in which $Asub\text{-}optimal_i$ is deforested in the baseline case	yr	5		calculated	each renewal of fixed baseline period
v	*1,2,3, …V:* type of surface to on which transport occurs	dimentionless	1		measured or estimated from literature	each renewal of fixed baseline period

176

V1i,t; V2i,t; ...;Vni,t	Variables included in a deforestation model		11	Unit of each variable to be specified by the project proponent	measured or estimated from literature	each renewal of fixed baseline period
VEF	Volume expantion Factor	dimentionless	A3-9		measured or estimated from literature	only once at project start
$VEX_{,w,j,fcl,t}$	Volume of timber for product class *w*, of species *j*, extracted from within *forest class fcl* at time *t*	m^3	A3-34		measured or estimated from literature	only once at project start and when mandatory
VOB10	Volume Over Bark above 10 cm DBH	m3	A3-9		measured or estimated from literature	only once at project start
VOB30	Volume Over Bark above 30 cm DBH	m3	A3-9		measured or estimated from literature	only once at project start
$Volume_{dc}$	Volume of lying dead wood in the density class *dc*	m^3	A3-30		measured or estimated from literature	only once at project start and when mandatory
V_{pl}	Commercial volume of plot *pl*	m^3 $plot^{-1}$	A3-19		measured or estimated from literature	only once at project start and when mandatory
V_{tr}	Commercial volume of tree *tr*	m3	A3-18, A3-21		measured or estimated from literature	only once at project start and when mandatory
w	1, 2, 3 … *W* Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other);	dimensionless	A3-34		defined	only once at project start and when mandatory
WW_w	Wood waste for wood product class *w*. The fraction immediately emitted through mill inefficiency	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start

177

XF	Plot expansion factor from per plot values to per hectare values	dimentionless	A3-12, A3-13, A3-16, A3-19, A3-20, A3-24		calculated	only once at project start and when mandatory

178