Application of the CCQI methodology for assessing the quality of carbon credits

This document presents results from the application of version 3.0 of a methodology, developed by Oeko-Institut, World Wildlife Fund (WWF-US) and Environmental Defense Fund (EDF), for assessing the quality of carbon credits. The methodology is applied by Oeko-Institut with support by Carbon Limits, Greenhouse Gas Management Institute (GHGMI), INFRAS, Stockholm Environment Institute, and individual carbon market experts. This document evaluates one specific criterion or sub-criterion with respect to a specific carbon crediting program, project type, quantification methodology and/or host country, as specified in the below table. Please note that the CCQI website Site terms and Privacy Policy apply with respect to any use of the information provided in this document. Further information on the project and the methodology can be found here: www.carboncreditquality.org

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Sub-criterion:	**1.3.2: Robustness of the quantification methodologies applied to determine emission reductions or removals**
Project type:	**Avoided unplanned deforestation** **Avoided planned deforestation**
Quantification methodology:	**VCS Methodology VM0009, Version 3.0** **Methodology for Avoided Ecosystem Conversion**
Assessment based on carbon crediting program documents valid as of:	**1 April 2024**
Date of final assessment:	**2 July 2024**
Score:	**1**

Assessment

Relevant scoring methodology provisions

“The methodology assesses the robustness of the quantification methodologies applied by the carbon crediting program to determine emission reductions or removals. The assessment of the quantification methodologies considers the degree of conservativeness in the light of the uncertainty of the emission reductions or removals. The assessment is based on the likelihood that the emission reductions or removals are under-estimated, estimated accurately, or over-estimated, as follows (see further details in the methodology):”

Assessment outcome	Score
It is very likely (i.e., a probability of more than 90%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals	5
It is likely (i.e., a probability of more than 66%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals OR The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) and uncertainty in the estimates of the emission reductions or removals is low (i.e., up to ±10%)	4
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is medium to high uncertainty (i.e., ±10-50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, but the degree of overestimation is likely to be low (i.e., up to ±10%)	3
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is very high uncertainty (i.e., larger than ±50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be medium (±10-30%)	2
It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be large (i.e., larger than ±30%)	1

Carbon crediting program documents considered

This assessment is based on an evaluation of the most important VCS documents applied under this methodology. It does not consider all VCS documents that may be applied in using the methodology. The following documents were considered:

1 Verra (2023): VCS Methodology VM0009. Methodology for Avoided Ecosystem Conversion. Version 3.3, 27 November 2023. https://verra.org/methodologies/vm0009-methodology-for-avoided-ecosystem-conversion-v3-0/

2 Verra (2024): VCS Standard. Version 4.6, 21 March 2024. https://verra.org/wp-content/uploads/2024/03/VCS-Standard-v4.6-watermark.pdf

3 Verra (2024): VCS Standard. Version 4.7, 16 April 2024. https://verra.org/wp-content/uploads/2024/04/VCS-Standard-v4.7-FINAL-4.15.24.pdf

Assessment Outcome

The quantification methodology is assigned a score of 1.

Note that Verra is in the process of phasing out this methodology and replacing it by the methodology VM0048. Specific transition requirements specify for how long this methodology may continue to be used.

Justification of assessment

Project type

This assessment refers to the following CCQI project types:

- **Avoided planned deforestation**: Activities to avoid legally authorized deforestation. In addition, forest degradation may be reduced. The activities are implemented on a dedicated project-level geographical area (not at jurisdictional level). Projects aim to stop deforestation that is planned by an identifiable, commercial agent. The project type reduces emissions by avoiding the loss of forest carbon stocks.
- **Avoided unplanned deforestation**: This includes activities to avoid not legally authorized deforestation which occurs as a result of socioeconomic forces, such as subsistence agriculture of local communities, encroaching infrastructure, and illegal logging. In addition, forest degradation may be reduced. The activities are implemented on a dedicated project-level geographical area (not at jurisdictional level). Projects usually combine different activities to address drivers of deforestation, for example, by improving agricultural practices of local communities or providing alternative livelihoods. The project type reduces emissions by avoiding the loss of forest carbon stocks.

The CCQI project types, as described above, are applicable to the methodology. The methodology also applies to activities to avoid unplanned degradation and activities that avoid conversion of native grassland and shrubland to a non-native state.

OE1 **Lack of clarity of definitions and applicability of different parts of the methodology:** The methodology explains that a native grassland or shrubland includes indigenous grass species and may include shrub and woody species which are below the forest definition used. The baseline part in section 6.3.2 explains further that native grassland and shrubland conversion shall be defined as conversion to anthropogenic use such as agriculture, development (including housing) or other anthropogenic land-use discernable from remotely sensed imagery and that conversion to grazing lands and/or pasture shall be excluded as conversion (p. 53). This should clearly be presented in the introduction/ applicability and the definition part of the methodology. The methodological approaches for avoided forest conversion and avoided conversion of native grasslands are not separated but entwined. However, the monitoring objectives and practices are quite different for forest conversion and grassland conversion. This can lead to mistakes in the interpretation of the methodology and in picking and choosing of applicable parts of the guidance and from this perspective result in overestimation of emissions and removals. The assessment of the methodology is also hampered by a lack of appropriate referencing to other VCS documents. For example, the definition of native ecosystem is referred to as "please see current VCS definition" without indicating a source or a link where the current VCS definition can be found. References in the list of references mostly do not include internet links or DOIs. This applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

Selection of emission sources for calculating emission reductions or removals

The methodology specifies mandatory and optional carbon pools and sources of emissions and excludes certain sources. It is assumed that rules for inclusion of carbon pools or emission sources apply to both baseline and project quantifications; however, the methodology does not state that explicitly. Table 1 provides a detailed assessment.

Table 1 Assessment of sources, sinks, reservoirs

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Carbon Pools		
Aboveground tree biomass from merchantable trees	Included when baseline scenario or project activity include the harvest of timber for production of long-lived wood products[1]; Otherwise optional	Major carbon pool affected by project activities. If no timber production occurs in the baseline and project scenario, exclusion of this source is conservative, since tree biomass from merchantable trees is likely to be larger in the project scenario than in the baseline scenario.
Aboveground tree biomass from other trees	Mandatory	Major carbon pool affected by project activities
Aboveground non-tree biomass	Included if the baseline scenario includes perennial tree crops; Otherwise, optional	In the baseline scenario (post-deforestation land-use for agriculture, without perennial crops), non-tree biomass such as shrubs are likely to be removed. Therefore, exclusion of this pool in the baseline scenario and the project scenario is likely to be conservative.
Belowground tree biomass (separated by methodology into merchantable and non-merchantable)	Optional, may be conservatively excluded	Major carbon pool affected by project activities. Belowground tree biomass is likely to be higher in the project scenario than in the baseline scenario. Therefore, exclusion of this carbon pool is conservative.

[1] Products derived from the harvested wood of a merchantable tree such as sawn timber and plywood that are assumed to remain or decay during the project crediting period.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Belowground non-tree biomass	Optional, may be conservatively excluded	Belowground non-tree biomass could be affected in different ways in the baseline scenario, depending on the agricultural practices. Non-tree biomass is likely to be removed and belowground biomass will be removed or disrupted to prepare the soil, resulting in a release of the stored carbon. However, while non-tree biomass may be initially disturbed and removed, it could also recover and potentially increase beyond the project scenario. Therefore, exclusion of this pool in the baseline and project scenario would lead to uncertainty. In most cases, however, we deem these effects to be negligible.
Deadwood	Included if aboveground merchantable trees pool is selected; Optional for standing deadwood and lying deadwood	Major carbon pool affected by project activities when harvesting merchantable trees. In the case of harvesting non-merchantable timber, in the baseline scenario, a potential increase in slash/lying deadwood would result from harvesting (which does not occur in the project) but when the land use shifts to agriculture then deadwood would be burned or removed. Standing deadwood would also be removed in the baseline scenario. The projects are likely to result in more naturally occurring deadwood (which would not occur in the baseline). Exclusion of deadwood in the project and baseline scenario is therefore conservative.
Litter	Excluded	In the baseline scenario, litter is likely to decrease due to removal of living biomass and deadwood for the purpose of site preparation for agriculture (e.g., biomass burning). Exclusion of this pool from the baseline and project scenario is therefore conservative.
Soil organic carbon (SOC)	Optional	In the baseline scenario, soil disturbance can be expected, leading to the release of SOC. In tropical regions, post-deforestation land use for agriculture is unlikely to increase SOC stocks. Therefore, exclusion of this pool from the baseline and project scenario is conservative.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Harvested Wood Products (long-lived wood products)	Included if aboveground merchantable trees pool is selected	Timber harvest/logging for production of short- and medium-lived wood products may occur as a first stage of land transition to agriculture in the baseline scenario. In the project scenario, forest protection would likely result in reduced logging levels relative to baseline and thus a decrease in the HWP pool. Therefore, exclusion of this carbon pool in the project and baseline scenario may not be conservative. The methodology requires inclusion when baseline scenario or project activity include the harvest of timber for production of long-lived wood products. This is generally appropriate, but this provision is limited to long-lived products, which could lead to overestimation for short- and medium-lived products.
Emission sources		
Emissions from biomass burning	CO_2 lacks clarity, not explicitly addressed	CO_2 emissions from fires are excluded because the methodology claims that they are already included in the changes of carbon pools. This does not account for biomass burning from carbon pools that are excluded. Exclusion of this source can therefore lead to overestimation.
	CH_4 and N_2O excluded	The methodology excludes CH_4 and N_2O emissions because higher emissions from fires are assumed to occur in the baseline than in project scenario. However, biomass burning may occur in project as a result prescribed burns or wildfires, therefore exclusion of this emission source my lead to uncertainty.
Emissions from the combustion of fossil fuels	Excluded (not addressed)	Exclusion may lead to uncertainty because emissions from combustion may increase or decrease as a result of project activities. However, this source is likely to be small.
Livestock emissions	CH_4 excluded in the baseline scenario; mandatory in the project scenario when emissions from grazing are not *de minimis*	If deforestation for livestock operations occurs in the baseline, then it is likely that livestock production will decrease due to the project or shift to other areas through activity shifting or market leakage (and remain at the same level as the baseline or decrease). Therefore, it is conservative to exclude this source from the baseline and project.
	N_2O excluded	Manure management is not allowed to take place under the methodology according to applicability condition 14. If manure management does not take place under the project scenario but may take place in the baseline scenario, exclusion of this emission sources is conservative.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
N_2O emissions from synthetic fertilizer	Included if not *de minimis*	In the baseline scenario, fertilizer use may increase or decrease over time, however, it is likely to cause more emissions than in the project scenario. Therefore, exclusion is conservative.

OE2 **Lack of guidance to test significance:** Other VCS REDD+ methodologies require that the CDM Tool for testing significance shall be used to determine insignificant carbon pools In VM0009 project developer needs to provide evidence for the conservative exclusion of any optional pools, but the tool is not mentioned. This gives additional flexibility to project proponent how they determine significant carbon pools and may lead to a selection that could overestimate. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is estimated to be **high**.

OE3 **CO_2 emissions from biomass burning are excluded**. CO_2 emissions from fires are excluded because the methodology claims that they are already included in the changes of carbon pools. This does not hold if biomass is burned from carbon pools that are excluded and therefore not accounted for. Therefore, exclusion of this source from the project scenario may lead to overestimation of emission reductions. The number of projects affected is **unknown**. The impact on total credited emission reductions is **unknown**. The variability in the degree of overestimation among projects is **unknown**.

OE4 **Inclusion of the HWP pool is optional for short- and medium-lived wood products**: Timber harvesting is likely to be larger in the baseline and in the project scenario. This may imply that the HWP carbon pool decreases as a result of the implementation of projects. The methodology accounts for long-lived HWP products but allows excluding of short- and medium lived products. This can lead to overestimation. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is **unknown**.

UE1 **Aboveground merchantable tree biomass is optional**: If no timber production occurs in the baseline and project scenario, exclusion of this source is conservative, since tree biomass from merchantable trees is likely to be larger in the project scenario than in the baseline scenario.. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is estimated to be **high** (larger than ±30%).

UE2 **Above ground non-tree biomass is optional to include in the project's forest carbon stocks**: In the baseline, deforestation would result in a lower amount of non-tree biomass than in the project with exclusion leading to underestimation. This issue applies to projects that opt to exclude above ground non-tree biomass. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE3 **Belowground tree biomass is identified as an optional pool**: In the baseline scenario, deforestation would likely result in a lower amount of belowground tree biomass than in the project scenario. Therefore, the exclusion of this carbon pool would likely result in underestimation of emission reductions. This issue applies to projects that opt to exclude belowground non-tree biomass. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE4 **Deadwood is an optional pool for some projects**: For projects that do not involve timber production for long-lived harvested wood products in the project scenario or in the baseline scenario, deadwood is an optional carbon pool. Naturally occurring deadwood (both standing and lying) is likely be lower in the baseline scenario than in the project scenario. Therefore, exclusion of this carbon pool is likely to lead to underestimation of emission reductions. This issue applies to projects that opt to exclude deadwood. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE5 **Litter carbon pool is excluded:** Litter is anticipated to decrease in the baseline scenario resulting from deforestation. Given that measuring litter would increase the emission reductions that could be quantified as project impact it is conservative to exclude litter. This affects **all** projects. The impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE6 **Soil carbon is identified as an optional source.** Soil carbon is anticipated to decrease in the baseline scenario, resulting from soil disturbance caused by deforestation, and may not be significantly impacted under the project scenario. Exclusion of this carbon pool therefore likely leads to underestimation of total credited emission reductions. This issue applies to projects that opt to exclude soil carbon. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE7 **Methodology excludes CH_4 emissions from livestock in baseline scenario:** Livestock emissions within project boundaries are likely to decrease compared to a baseline scenario where deforestation occurs to enable livestock production. Excluding livestock emissions from baseline is therefore likely to result in underestimation of emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE8 **N_2O emissions from the application of fertilizer may be excluded**: The use of fertilizer in the baseline and project scenario is highly dependent on local conditions and common fertilizer use. If fertilizer use does not increase due to leakage prevention measures, we expect fertilizer use to decrease in the project scenario relative to baseline levels because more land did not shift to agricultural use (in which case fertilizer may have been used). Therefore, the exclusion of this source is conservative. The number of projects affected by this is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

Un1 **Emissions of CH_4 and N_2O from biomass burning are excluded**: The methodology seems to implicitly assume that biomass burning occurs more in the baseline than in the project scenario. However, this assumption is not necessarily correct. Burning can occur from wildfires or prescribed fires as part of forest management under the project. The degree of burning may strongly depend on climate conditions in specific years and management objectives. Therefore, exclusion introduces uncertainty in the quantification of emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, this issue introduces a **low** (less than 10%) degree of uncertainty to the estimation of total credited emission reductions. The variability in the degree of uncertainty is **unknown**.

Un2 **No consideration of CO_2 emissions from fossil fuels**: Given that CO_2 emissions from the combustion of fossil fuels may occur in the baseline related to harvesting and agriculture and in the project scenario related to monitoring and patrolling, it is uncertain – and likely variable among projects – whether these emissions decrease or increase as a result of the implementation of the project. This introduces uncertainty in the quantification of emission reductions. The number of projects impacted by this issue is **unknown**. For those projects where this issue materializes, this issue introduces a **low** (less than 10%) degree of uncertainty to the estimation of total credited removals or emission reductions. The variability in the degree of uncertainty is **unknown**.

Though our assessment is limited to avoided deforestation, we note that the methodology provisions on the selection of carbon pools are not appropriate for avoided conversion of native grasslands which is also applicable under this methodology. The conversion of native grasslands to other anthropogenic land uses may release emissions from soil carbon. However, the accounting of soil organic carbon – which is the major carbon pool affected by a conversion of native grasslands is optional for the accounting and 'may be conservatively excluded' (Table 2, p. 41). The second carbon pool affected is a loss of aboveground non-tree biomass and related emissions from shrubs if present on the native grasslands. The accounting of above-ground non-tree biomass (this means the shrubs) is also optional or excluded ('may be conservatively excluded') (Table 2, p. 41) unless the baseline includes perennial tree crops which is not the case for native grasslands because the shrubs are not planted and are not crops. This means all relevant carbon pools for the case of avoided conversion of native grasslands to other anthropogenic land-uses are optional or may be conservatively excluded. These methodology provisions do not make sense for the avoidance of conversion of native grasslands.

Determination of baseline emissions

In the following, we first provide an overview of general challenges regarding the determination of baseline deforestation levels. This is followed by a summary of the issues identified with baseline determination under the older VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, and VM0015). We then turn to a detailed assessment of this methodology.

General challenges in establishing baselines for avoided deforestation projects

Establishing baselines for avoided deforestation projects is associated with very large uncertainty. Establishing baseline is always associated with uncertainty, as it is not directly observable what would have happened in the absence of a project. For avoided deforestation projects, uncertainty in establishing baselines is particularly high. The rate of future deforestation in a particular forest area depends on many unknown factors, such as changes in political, economic and social conditions. The literature suggests that changes in such “confounding” or “exogenous” factors can have a large impact on avoided deforestation (see, for example Miranda et al. 2024). Uncertainty in the underlying (historical) data used to establish baseline deforestation rates is another important source of uncertainty.

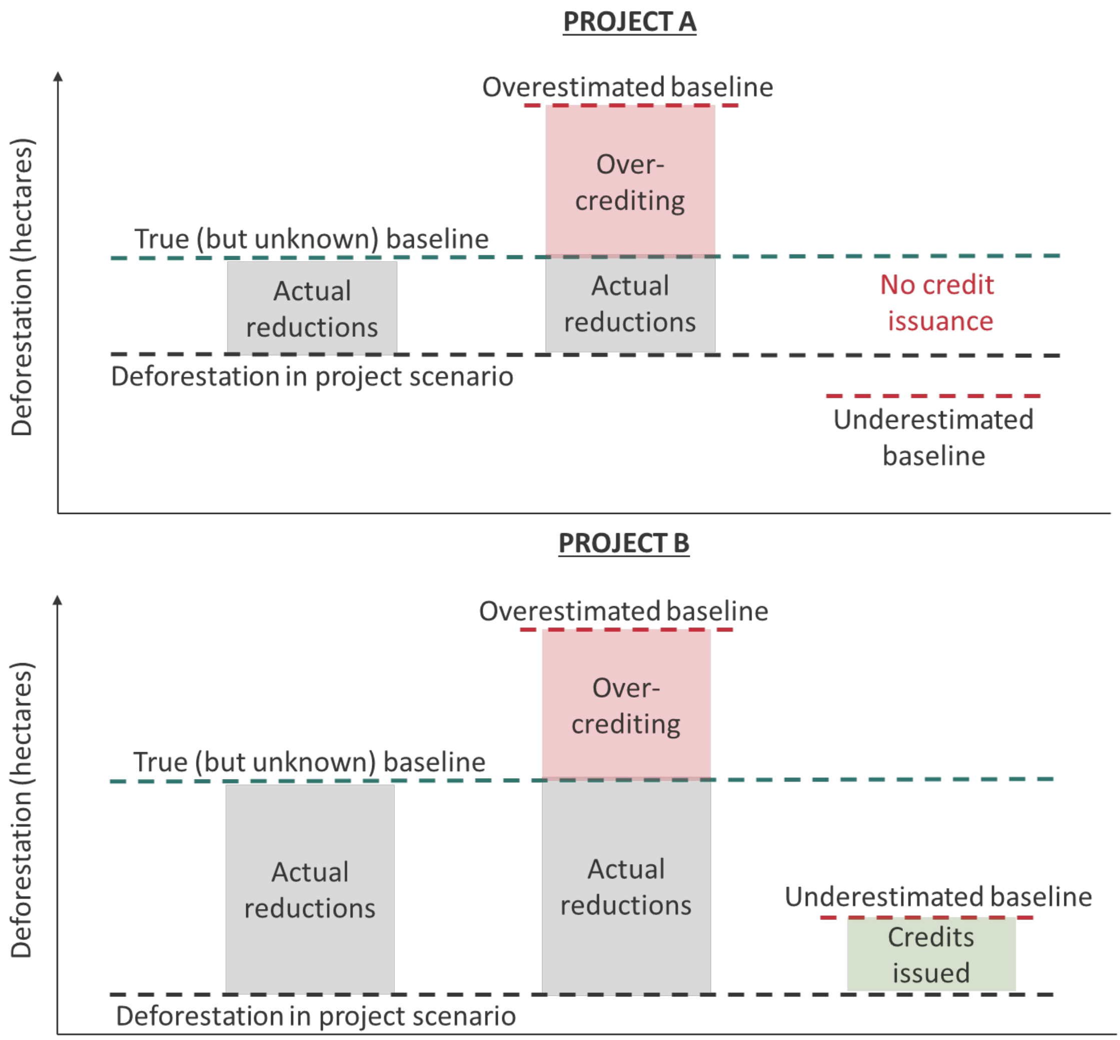
The divergence in estimates of baseline deforestation rates for the same projects is an indicator of the large uncertainty associated with predicting future deforestation rates for a specific project. For example, Guizar-Coutiño et al. (2022) and West et al. (2023) arrived at the different baseline deforestation estimates for the same projects. Similarly, some rating agencies built their own models to assess the quality of baselines and arrived at different deforestation baselines as the underlying projects. Aggregated estimates between rating agencies also differ (Calyx Global 2023; Sylvera 2023). Another indicator for the uncertainty is that even at jurisdictional level deforestation rates can vary considerably over time.

Large uncertainties raise challenges for ensuring attributability of the emission reductions to the project intervention. As the uncertainty in future deforestation scenarios is very high, this poses the risk that the calculated emission reductions could only partially be attributable to the project intervention and partially be an artefact of wrongly set baselines. This is illustrated in Figure 1 through two hypothetical projects. Project A reduces deforestation to some extent, by about one third. In this case, a large overestimation of the baseline would lead to significant over-crediting. A large underestimation of the baseline may lead to no carbon credit issuance at all, although the project reduces deforestation. This challenge is lessened for project B. Here the project reduces deforestation close to zero. In this case, an overestimation of the baseline leads to a lower degree of over-crediting relative to the actual reductions. Moreover, the project would still receive carbon credits if the baseline were significantly underestimated.

Two issues arise from this challenge:

1. **It is important to address the large uncertainty in predictions about future deforestation levels, by choosing a scenario that is conservative in the light of the uncertainty.** In theory, one could argue that over-crediting in one project may be compensated by under-crediting in other projects. However, projects with overestimated baselines have a competitive advantage over other projects. They receive more carbon credits than their actual emission reductions and can thus offer carbon credits at lower prices. By contrast, projects with underestimated baseline may not receive any carbon credits at all (as illustrated in Figure 1 above) or may only receive fewer carbon credits. Some of these projects may thus not succeed, or may fail later on, as they cannot generate sufficient revenues from carbon credits. This would lead to more carbon credits being generated from projects with overestimated baselines. Therefore, in a competitive market, unaccounted baseline uncertainty can undermine integrity across a portfolio of projects. Underestimation in some projects does therefore not compensate for overestimation in other projects. This is why many standard setting organizations, such as the Integrity Council for the Voluntary Carbon Market, require that uncertainty is addressed at the level of each individual mitigation activity and not only across a portfolio of projects and that all sources of uncertainty are considered. To address this issue, baselines need to be set at a sufficiently conservative level where the degree of conservativeness takes into account the level of uncertainty.

Figure 1 Implications of uncertainty in baseline deforestation levels



2. **It is important that projects have a significant impact on deforestation levels.** The larger the impact of project interventions on deforestation drivers relative to the impact of confounding or exogenous factors is, the more likely it is that the emission reductions are attributable to the project interventions. As shown in Figure 1 above, the implications of baseline uncertainty are mitigated if projects strongly and effectively reduce deforestation drivers. The available literature indicates that this may not always be the case for avoided unplanned deforestation projects. Projects often aim to create alternative sources of income for local communities, through improving existing agricultural techniques on existing farmland, developing agroforestry systems or establishing fisheries and aquaculture. However, in some cases, projects only reached certain groups and failed to address those communities which are most dependent on the forest as a source of income (Haya et al. 2023; Kapos et al. 2022), Another driver of deforestation are unclear land tenure structures, which some projects address through supporting land tenure reforms. However, research showed that improving land tenure is immensely difficult, as the local context and the individual interests of affected groups needs to be appropriately considered to ensure that the relevant groups receive tenure rights and to avoid that new tenure arrangements create conflict (Sunderlin et al. 2018; Alusiola et al. 2021). Lastly, projects oftentimes implement measures to prevent illegal logging, such as forest patrols, monitoring posts or marking forest boundaries. While these measures might reduce deforestation, they are not always implemented

stringently enough (Nathan and Pasgaard 2017). To ensure that project activities are effective – and thereby mitigate the impact of baseline uncertainty – methodologies could require monitoring of the implementation of the project interventions or that projects must reduce deforestation to levels close to zero in order to receive carbon credits.

Summary of issues observed with the older VCS methodologies

All older VCS methodologies assume historical deforestation rates or trends to continue in the future. Different approaches exist for constructing baselines for avoided deforestation projects (West et al. 2023; Haya et al. 2023). The basic approach taken by all older VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, VM0015) is assuming that historical deforestation rates or trends observed in a reference area will continue in the future. The methodologies use historical information from a period covering the last 10 to 15 years prior to the project start date to establish historical deforestation rates or trends. The project-specific reference region to determine historical deforestation must be similar to the project area and methodologies provide criteria and ranges in which the project area and reference region may differ. These four methodologies use the historical average deforestation or different regression models for making a prediction about future deforestation or future forest cover (see Haya et al. 2023 for a detailed comparison of regressions used by the four assessed Verra methodologies).

Flexibility in establishing baseline deforestation rates. The four older VCS methodologies (VM0005, VM0007, VM0009 and VM0015) provide considerable flexibility on how to establish baseline deforestation rates. This allows project developers to make subjective choices that can lead to higher baselines (Haya et al. 2023). This holds in particular for the following choices:

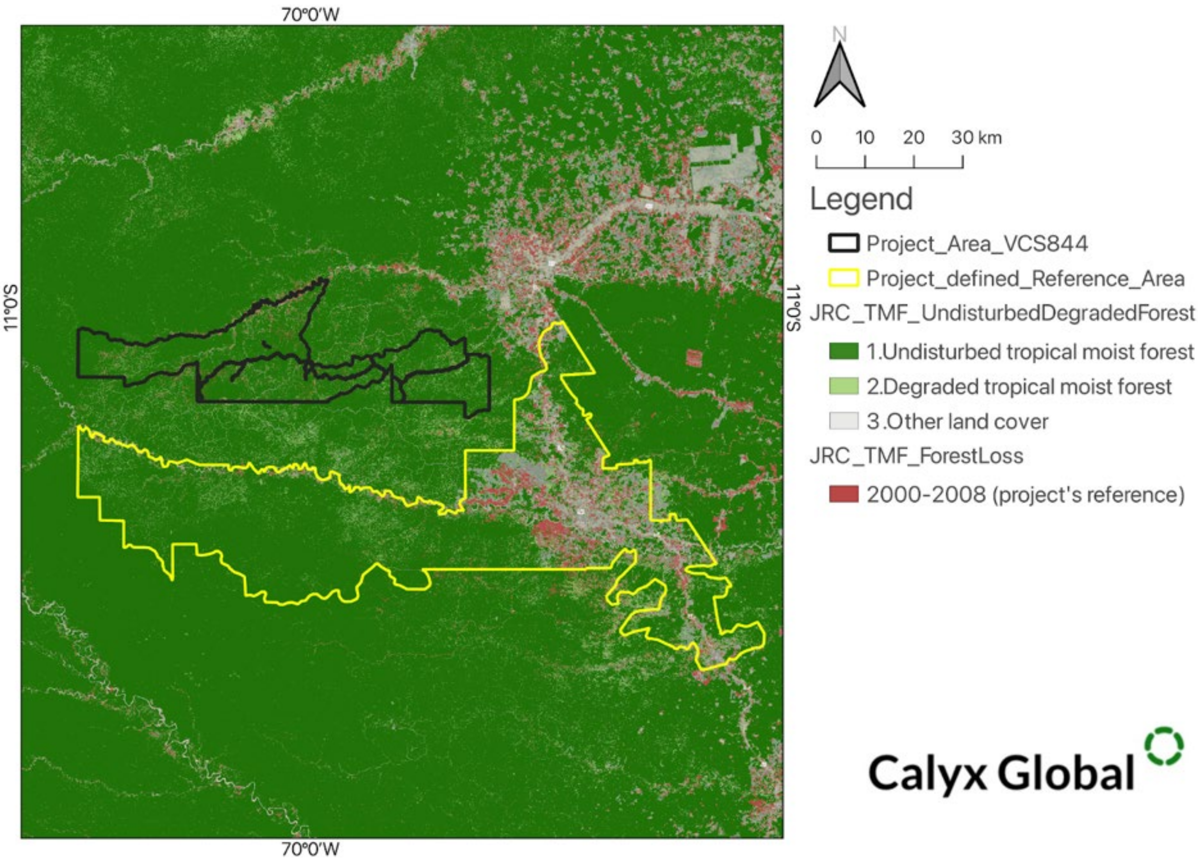
- **Choice of the reference area or region:** The historical deforestation in a reference region is used to estimate the baseline deforestation rates. Although the methodologies provide criteria for ensuring that reference areas match the characteristics of the project area, these do not necessarily prevent project developers from choosing reference areas with high levels of historical deforestation (Seyller et al. 2016). Reference regions may especially be biased towards higher deforestation rates if the methodology provides different options to project developers to choose from or if deviations are explicitly allowed. For example, the methodology VM0007 stipulates that road density (m/km) may be up to 20% higher in the reference area than in the project area and roads are known to facilitate deforestation (see module VMD0007).

- **Approaches to projecting the historical deforestation trends into the future:** The projection of historical deforestation trends into the future may be done by using the average historical values or through models. If choice is given between approaches or within an approach, project developers may choose options that result in higher baseline deforestation rates.

- **Choice of the historical reference period:** The length of the historical reference period and how much time lies between its end date and the start of the project are two variables that influence the estimates of baseline deforestation. If the methodology allows for flexibility in choosing the historical reference period, project developers may choose a period that results in higher baseline deforestation rates.

This is illustrated in Figure 2 for the VCS project 844. The reference region (yellow lines) includes an area with roads and settlements in which significant deforestation has been observed in the reference period. The project area (black lines) is further away from roads and is thus likely to face much lower deforestation risks.

Figure 2 Project area and reference region used for estimating the rate of baseline deforestation for the project VCS844



Note: Figure provided by Calyx Global.

The available literature suggests that baseline deforestation rates derived from these older VCS methodologies have likely been overestimated by several hundred percentage points on average. Several studies have evaluated the impacts of projects by comparing the project areas to well matched control groups (West et al. 2023; Guizar-Coutiño et al. 2022; West et al. 2020). For example, West et al. (2023) estimate that only about 6% of the credits issued to the sampled projects represent actual emission reductions. Estimates by Guizar-Coutiño et al. (2022) are somewhat higher but still point to very significant overestimation. Inflated baselines are identified as the major cause of overestimation. Rating agencies that evaluated individual projects come to similar conclusions. Calyx Global (2023) evaluated 73 avoided deforestation projects and concluded that only four projects estimated a conservative baseline. Sylvera (2023) assessed more than 85% of avoided deforestation credits on the market and concluded that 31% of the projects were of "high-quality". Field-based case studies also find high risks of overestimation due to inflated baselines (see for example Seyller et al. 2016). Haya et al. (2023) applied the four older Verra methodologies assessed by CCQI (VM0006, VM0007, VM0009 and VM0015) to the same four projects and arrived at baselines that varied by a 1459% on average for the same project. This illustrates that the application of these methodologies to the same project can lead to greatly varying baselines. They also found that baselines used by project developers were consistently at higher end of the range of baselines they constructed by applying the four methodologies, suggesting that project developers made choices among the available options that led to higher baseline estimates.

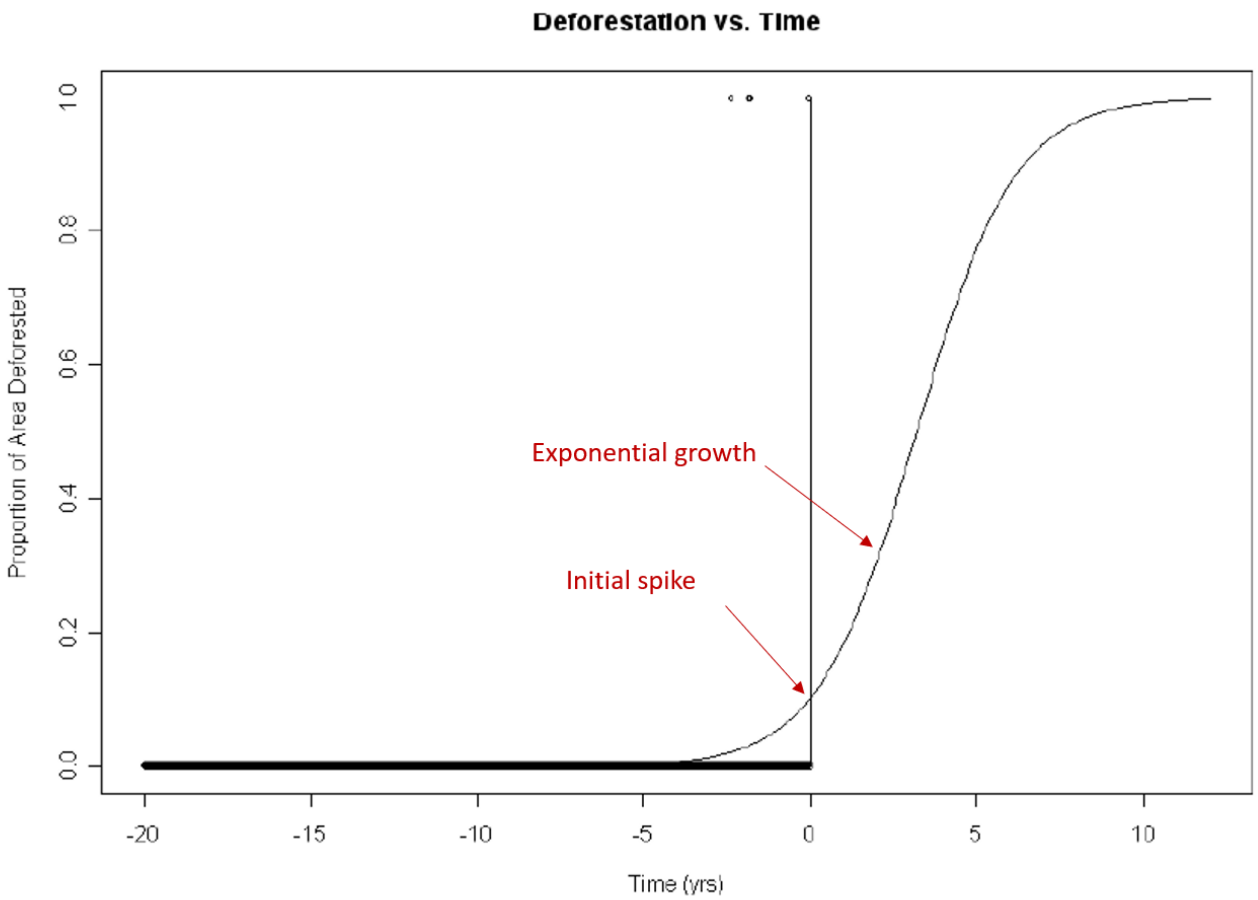
Assessment of VM0009

This methodology uses historical carbon stock changes in a reference region to determine baseline emissions. The baseline validity period was originally ten years and is six years since version 4.2. of the method ology (VCS Standard v4.2 and v4.7).Baseline emissions are estimated for so called “project accounting areas”, which comprise the areas where the project is being implemented. One project can have several accounting areas, each with its own baseline. Accounting areas must have been forested 10 years prior to the project start date and at the time of the project start date. In addition to the project accounting areas and the reference areas, the methodology also defines “proxy areas”. These areas are used to determine residual carbon stocks after deforestation and conversion to the final land use. They may overlap with the reference area and must exclude the project area.

The methodology uses a logistic regression to model cumulative forest loss over time. Sample points of land cover observations (forest vs. non-forest) in a reference area over a historical reference period are used to fit the model. The methodology pre-establishes six baseline types. For each baseline type, the methodology specifies a logistic equation and the model parameters that must be used. Which of the baseline types should be applied by a project, depends on the results of an analysis of agents or drivers of deforestation as well as the proximity of the project area to previous deforestation and to the reference area. Three baseline types are categorized as “planned conversion” and three as “unplanned conversion”. Under the planned conversion baselines, it is assumed that the primary agent of deforestation carries out commercial harvest (legally or not legally sanctioned) followed by conversion to agricultural land by secondary agents, which may do so legally or illegally (e.g. small scale agriculture). If this pattern cannot be demonstrated, baselines for “unplanned conversion” apply. Three baseline types are provided for this, which differ in how much of the perimeter of the project area was within 120m of deforestation in the 10 previous years and whether the project area and the reference area are adjacent to each other. In addition to the logistic regression model described above used to estimate forest loss (and associated emissions from biomass), the methodology also uses a specific model to estimate emissions from soils if the soil organic carbon pool is included. It assumes an exponential decay of soil organic carbon. If the deadwood and HWP pool are included, linear decay over a ten-year period is assumed. If SOC is included, an exponential decay over time is assumed.

OE5 **Use of logistic regression to model deforestation:** The use of a logistic regression assumes that baseline deforestation will see an increasing trend. The methodology states that the use of logistic regression is substantiated by literature but one of the sources cited (Mahapatra and Kant 2005) argues that a multinomial logistic regression, which uses continuous variables, delivers better predictions than a binary logistic regression as used in the methodology. According to Haya et al. (2023), two issues related to the logistic regression contribute to inflated baselines (see Figure 3). First, the exponential growth in deforestation rates in the early years of the project may be unrealistic for many projects. Second, the approach may result in an initial “spike” in deforestation levels at the project start date (time 0). This may occur because the starting point of the regression may be prior to the project start date. The initial spike in deforestation levels at year 0 also contradicts the requirement in the methodology that the project accounting area needs to be forested at the project start date. For these reasons, for many projects the use of the logistic regression approach is likely to lead to overestimation. This is likely to affect a **high number of** projects. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **high** (larger than 30%). The variability among those projects for which the issue materializes is **unknown**.

Figure 3: Exemplary logistic function of deforested area showing two instances of potential over estimation (image modified from VM0009 v.3.0)



Source: Figure 8 on page 78 of version 3.0 of VCS methodology VM0009. Arrows and text in red added.

OE6 **Flexibility in choosing the start date of the historical reference period:** The methodology does not prescribe the length of the historical reference period, it does not provide a start date (in the past) or an end date. Instead, the start date of the reference period is tied to the deforestation agent and hence the baseline type (see section 6.8.2). We assume that the end date is equal to the project start date, but this is not explicitly stated. For baseline types for planned deforestation, if the commercial agent is known, the historical reference period starts when the agent acquired the land in the reference area or when management practices changed due to laws, access to market, technology or other reasons. For baseline types for unplanned deforestation important historic events can be used to determine the historical reference period. These include the arrival of "specific foreign agents of conversion", "times when the drivers of conversion became apparent", "times of significant economic growth or decline". Either expert knowledge or participatory rural appraisal can be used to determine these events. In addition, imagery from before and after the event needs to be available. If no events can be identified, the availability of historical images of the reference area is used to establish the start of the reference period. None of these options provides guardrails against bias. The different options available to project developers give them considerable flexibility in choosing a reference period that leads to higher baseline deforestation estimates. This can lead to overestimation. The number of projects affected is **unknown**. The impact on total credited emission reductions and the variability in the degree of overestimation among projects are also **unknown**.

OE7 **Flexibility in choosing the reference area:** The methodology requires project developers to establish a reference area for each accounting area. The methodology states that the reference area "is located in the same region as the project area and where historical conversion is observed. The reference area is similar to the project accounting area in most respects and represents what would have happened in the project accounting area in the baseline scenario over time" (p.19). The reference area is defined differently for the specific baseline types, but the selection criteria apply to all baseline types. These criteria intend to ensure similar agents and drivers of deforestation between the project area and the reference area. Although referred to as selection criteria, no benchmarks for a deviation in similarity are provided that would allow for a selection. The criteria are more like information requirements. For example, regarding size and location, "a pair of maps showing the boundaries and size of the reference area and the project accounting area, including an indication of their locations relative to each other" and a "written justification for the selection of the location of the reference area" are required. Regarding drivers of conversion, descriptions of the socio-economic and cultural conditions in the reference area and the project accounting area are required. Descriptions are also required for the location of agents and their mobility. Regarding the landscape configuration (topography, land use and land cover, soil, infrastructure, infrastructure, etc.) a paired map comparison of the reference area and the project accounting area and a written justification of the similarity are expected. For planned deforestation baselines, the reference area the "reference area must have as much forest as the project accounting area at some point in time during the historical reference period". For planned deforestation projects, the reference area must be controlled by the "same specific primary agent of conversion" or by the class of agents, if the specific agent cannot be identified. Landholdings of multiple agents can also be combined, to ensure that the reference area has as much forest area as the project accounting area at some point in time during the historical reference period. For unplanned deforestation, flexibility in the location of the reference region is provided, as it "must be in the same general region as the project area, but not necessarily adjacent to the project area". Like for unplanned deforestation, forest cover in the reference region must have been the same as in the project accounting area. Additionally, requirements for certain elements that should form part of the reference area boundary are included (e.g. environmental, natural or political boundaries, transport infrastructure, land ownership). The methodology also requires that "project proponents should choose boundaries for the area that result in a conservative baseline scenario", but no further guidance on how to ensure conservativeness is given. The methodology thus provides considerable flexibility to project developers to select reference areas that lead to higher baseline deforestation estimates. This flexibility likely leads to overestimation. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to **high** (larger than 30%). The variability among those projects for which the issue materializes is **unknown**.

Un3 **Flexibility in choosing the proxy area:** The proxy area is used to estimate residual carbon stocks after deforestation. The proxy area should be selected by project developers using similar criteria as for the selection of the reference area. Additionally, project developers must demonstrate that the proxy area has been converted as of the project start date, using spatial analysis. For each baseline type applied in a project, a separate proxy area must be established. Whether the carbon estimates of the proxy area represent an accurate estimate of the post deforestation carbon stocks, depends on the actual post deforestation land use and not the assumed one. If the actual post-deforestation land use has a higher carbon stock than the one assumed in the baseline, this would lead to overestimation, in the opposite case, the approach could lead to underestimation. Like for the reference area, the guidance for selecting the proxy area provides considerable flexibility to project developers and no concrete thresholds for a deviation in similarity are provided. The number of projects affected is **unknown**. This issue introduces a medium degree of uncertainty to the estimation of total credited removals. The variability among those projects for which the issue materializes is unknown.

Un4 **It is optional to determine a minimum sample size for sample points in the reference area**: The methodology explicitly states that the sample size determination is optional, "but a minimum sample size may be estimated within +/- 15% of the estimated proportion of conversion in the reference area during the historic reference period" (see section 6.8.5). Alternatively, it indicates that "a good minimum sample size is approximately 300 points". If a small sample size is used, this may lead to a confidence deduction. The number of projects affected by this is **unknown**. The flexibility introduces a medium degree of **uncertainty** to the estimation of total credited emission reductions. The variability among those projects for which the issue materializes is **unknown**.

Un5 **Insufficient guidance for determining co-variates in the fitting of the biomass emission model:** Haya et al. (2023) indicate that as of March 2022, two projects used population density as additional covariate. All other projects used time as the only predictor. This may be a result of the little guidance that is given with regards to the selection and use of covariates. Covariates, especially proximity to a previously deforested area, accessibility and existence of settlements have been identified to be effective in predicting deforestation with logistic regressions (Ludke et al. 1989). It is not known whether better use of covariates by project proponents could lead to better predictions of deforestation or to under- or overestimation. The number of projects affected by the issue is **unknown**. The issue introduces a **high** degree of uncertainty to the amount of total credited emission reductions. The variability among those projects for which the issue materializes is **unknown**.

UE9 **Exclusion of emissions and removals related to logging:** The methodology excludes emissions from residual damage caused to standing trees by logging and potential removals from regrowth after logging. This is stated to be a conservative approach, since the project does not account for the reduced emissions from avoiding residual stand damage and does not account for removals from regrowth. This provision therefore likely leads to underestimation. This mainly applies to baseline types for planned conversion where the primary agent carries out logging. **All** projects with planned deforestation baselines are affected by this issue. The impact on total credited emission reductions or removals is likely to be **low** (less than 10%). The variability in the degree of underestimation among projects is **unknown**.

Quantification of carbon stocks in the project and the baseline scenario

VM0009 is different from other VCS methodologies as it includes all biomass carbon pools in a single model which are parameterized based on a range of baseline types. Parameters to these models are partially determined using a reference area. The intent of these models is to provide simplified accounting with clear and user-friendly implementation. This approach dramatically reduces the number of parameters and equations in the methodology relative to the other VCS methodologies.

Under this assessment, it was not possible to analyze the approaches in detail, as it would be necessary to test the biomass models in practice and compare with other approaches.

We identify the following elements of possible overestimation, underestimation or uncertainty with the approach in the methodology:

OE8 **Lack of appropriate definitions of forest, deforestation and degradation:** There is no requirement that the project proponents need to develop an appropriate definition of forest, deforestation and forest degradation for the project. Guidance would be necessary related to the choice of forest definitions (and related impacts on degradation) for different forest types, biomes or ecosystems and related to the definition of degradation, taking into account the specific features of the ecosystems in the project and the planned monitoring methods. Some projects implemented under the methodology use very low thresholds for canopy cover for humid tropical rainforests (e.g., a 10% canopy cover is used by the Mai Ndombe REDD+ Project which is one of the largest projects under VM0009). A 10% canopy cover is, however, far too low for a natural humid tropical rainforest where canopy cover of an intact forest may be 75-100%. Such low choice of canopy threshold implies that 90% of the trees could be deforested but the method would still classify the area as forest and multiply the area with a biomass factor for intact forests to quantify the carbon stocks prevented from deforestation. Thus, the lack of guidance related to a project-specific appropriate forest definition allows projects to define forests in a way that emissions from large-scale degradation /deforestation are not accounted for by the project. At the same time, the use of biomass stocks based on intact forests may significantly overestimate the emission reductions from deforestation. This is because the project may avoid deforestation in areas where the forest has already been severely degraded (e.g., leading to canopy cover of 20%). Fernández-Montes de Oca et al. (2022) show the importance of the definition of deforestation for the detection of deforestation. We assume that this issue affects **all** projects. The degree of overestimation of total credited emission reductions is **unknown**. The variability in the degree of overestimation among projects is also estimated to be **high**.

Un6 **Overall uncertainty assessment:** As an overarching issue, we observe that the methodology does not address uncertainty in determining carbon stocks in a systematic and appropriate manner. The methodology does not define an overall minimum level of accuracy for the determination of carbon stocks in the baseline and project scenario and lacks a systematic approach to account for uncertainty. This could be implemented by calculating error propagations and applying an uncertainty deduction based on the total error or by ensuring that uncertainty is addressed for all relevant parameters (e.g., by choosing a conservative value that reflects the uncertainty). In our assessment, the lack of provisions to address uncertainty in an appropriate manner, combined with outdated approaches and flexibility for project developers to choose between different approaches, results in a very high uncertainty in the quantification of carbon stocks, with results that may significantly differ from actual carbon stocks existing in the projects. This issue applies to **all** projects. The level of uncertainty and variability among projects are **unknown**.

Un7 **Outdated methodological basis:** The methodology only refers to the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003 report as a source of biomass data, soil organic matter, natural regeneration, firebreaks, CH_4 from rice cultivation and other parts of the emission reduction estimation. This is an outdated source. There are four relevant updated methodology reports published by the IPCC:

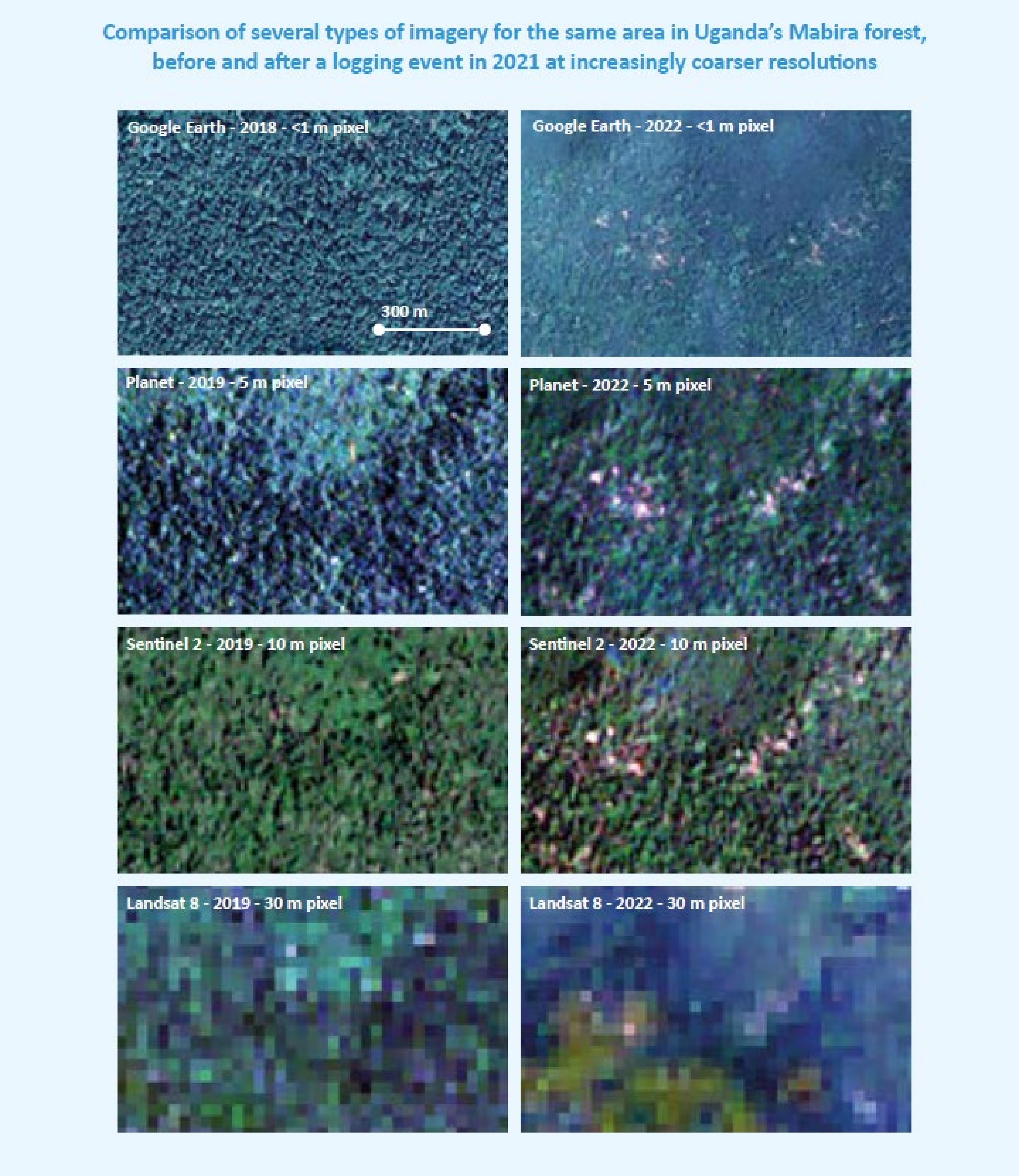
- The 2006 IPCC Guidelines for National Greenhouse Gas Inventories

- 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands
- 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

The newer reports include more specific and much more appropriate emission factors and other parameters, in particular for developing countries. The outdated references unnecessarily lead to higher uncertainties in the estimation. This issue applies to **all** projects. The level of uncertainty and variability among projects are **unknown**.

Un8 **Specific guidance missing for remote sensing:** The methodology does provide more specific guidance related to the determination of the forest or grassland areas with remote sensing methods compared to other REDD+ methods. Validation imagery has to show the adequacy of the spatial resolution to be interpreted. Remote sensing methods have developed tremendously in the past decade and satellite data with high-resolution images has become freely available. This development is not reflected in the methodology. Any up-to-date methodology with acceptable uncertainty for avoided deforestation activities would need to develop more specific guidance for project developers related to remote sensing data. Through Norway's International Climate & Forests Initiative, for example, anyone can now access Planet Labs's high-resolution, analysis-ready mosaics of the world's tropics. Real and False-color mosaics of <5 m/px mosaics of the tropics with monthly cadence from August 2020 onwards (and an archive from December 2015 – August 2020 of Bi-Annual mosaics) offer a tremendously improved understanding of the forest areas, deforestation and forest degradation as it uses the Near Infrared (NIR) band. FAO has developed ready-to-use tools under OpenForis (http://openforis.org), e.g. CollectEarth, EarthMap or SEPAL that provide high accuracy remote sensing data. VM0009 allows medium resolution imagery from Landsat with 30 m resolution. Figure 4 shows the difference in the quality of detection of logging events. Landsat 30 m pixels are the pictures in the lowest row. The method also requires manual image interpretation (p. 75) and does not allow automated image classification techniques. This may have been more accurate when the methodology has been developed, however automatic analysis of satellite data has been developed significantly and this recommendation may no longer be valid. The drastic improvements in remote sensing data for forest monitoring are not reflected in the methodology. This issue introduces significant uncertainty in the quantification of carbon stocks. We assume that this issue affects a **high** fraction of projects, assuming that only few projects may use more accurate data as required under the methodology. The level of uncertainty and the variability among projects are **unknown**.

Figure 4 Example demonstrating the comparison of remote sensing images to detect logging in a forest in Uganda



Source: Neeff et al. (2023)

OE9 **Insufficient guidance for ground truthing:** The calibration of medium-resolution remote sensing data is done with high-resolution imagery. It is not mentioned that there should be direct field observations used for ground-truthing and checking whether the remote sensing data has been correctly analysed. Ground truthing with field observations is essential for quality assurance of project-level land classification. Visual interpretation of higher-resolution images is not a valid ground truthing and calibration method. Ground truthing based on field observations should be mandatory and more specific guidance on the quantity and sampling methods for field observations should be provided. This issue introduces significant uncertainty. Moreover, it could also lead to an overestimation of emission reductions, as project developers may have leeway to interpret data in ways that provide larger emission reductions. We assume that this issue affects a **high** fraction of projects, assuming that only few projects use appropriate ground truthing approaches. The degree of overestimation and variability among projects are **unknown**.

Un9 **Insufficient guidance on forest stratification:** The methodology does not require stratification of forest areas. Stratification is only recommended, but not strictly required despite the fact that stratification is key for enhanced accuracy in large project areas. The stratification is important to link the detected areas of the forest strata with the appropriate biomass factors for the strata. Without appropriate stratification, biomass factors used will be associated with very high uncertainties. This issue introduces significant uncertainty. This issue is likely to apply to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

OE10 **Lack of clarity in determining merchantable trees used for long-lived products**: The methodology lacks clear guidance on how merchantable trees used for long-lived products should be differentiated from other trees. The methodology refers to expert knowledge, participatory rural appraisals or third-party publications to distinguish these types of trees. This provides considerable flexibility to project developers to define only a very narrow set of trees as merchantable and used to produce long-lived products. This could lead to underestimation of the carbon stored in the harvested wood products pool in the baseline scenario and thus underestimation of total credited emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is estimated to be **high**.

Un10 **Outdated guidance on harvested wood products:** The methodology is using an outdated method based on Winjum et al. (1998) for the estimation of carbon stored in wood products despite the fact that more recent IPCC methods exist, in particular in the 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories. The suggested method is not in line with the IPCC methods because it entirely ignores any country-specific data on wood products which are generally available for all countries from FAO wood statistics. Instead, the method uses default fractions for the carbon stored in different wood products and default parameters for the oxidation in four wood product classes for three climate regions. The IPCC Guidance states that, in order to calculate storage in harvested wood products, country-specific information on the utilization of wood as material needs to be available. If this is not the case, it should be assumed that the wood is oxidized within short periods after harvesting.

The methodology uses a wood product called “other industrial round wood” which does not exist in the IPCC methods and the international classification system for wood products which is used in FAO statistics. Industrial roundwood is roundwood without fuelwood and charcoal and is the material of origin for sawnwood, wood-based panels and paper and paperboard. It therefore does not make sense to estimate “other industrial round wood” separately. This seems to lead to some double-counting of harvested wood products.

The decay of wood products follows a first order decay function which is not reflected in the equation and approach described in Appendix C which is using annual oxidation factors over 95 years. The impact of this issue is proportional to the levels of harvested timber in the baseline and the actual project period. For a project, it would certainly be possible to track the main pathways of the harvested timber (whether it is delivered to sawmills for construction purposes or to pulp and paper production) and use these pathways for the calculation of carbon stored in wood products. The outdated standard factors introduce additional uncertainties. Overall, due to these issues, the estimation of carbon stored in harvested wood products may differ substantially from the real release or sequestration to or from the atmosphere. This issue is likely to apply to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

OE11 **Lack of binding character of essential parts of the methodology:** The procedures for estimating the carbon stock in each pool are detailed in Appendix B. However, the methodology allows that “Project proponents may deviate from the procedures detailed in Appendix B per current VCS requirement, including a description of the deviation and justification for the deviation.” (p. 124). As this is the key part of the carbon stock measurement, the method allows a wide range of unspecified deviations and does not require that the deviations have to increase accuracy and shall not decrease accuracy of the monitoring. The option to pick and choose deviations from the methodology can be used to bias the methods towards overestimation. The number of projects affected is **unknown**. The impact on total credited emission reductions and the variability in the degree of overestimation among projects are also **unknown**.

OE12 **Flexibility in choosing allometric equations:** Allometric equations are used to estimate the volume or biomass of trees based on parameters that are more easily to measure (e.g., height and trunk diameter at breast height). Allometric relationships can be determined based on destructive sampling of trees. Given the costs of destructive sampling, carbon crediting projects usually use literature sources of allometric equations. The quality of allometric relationships is best if the determination is site- and species-specific and from the same or a similar location. The determination of aboveground biomass through allometric equations is associated with considerable uncertainty, in particular in the case of tropical forests where the choice of allometric equations has been identified as a main source of error. Three important shortcomings have been identified: equations are constructed from limited samples; they are sometimes applied beyond their valid diameter range; and they rarely take into account the wood’s specific density (Martínez-Sánchez et al. 2020; Chave et al. 2004; van Breugel et al. 2011).

VM0009 allows the use of allometric equations from existing IPCC, government, or peer reviewed literature (p. 109). When equations are selected from literature, justification must be provided for their applicability. The methodology does not provide a clear ranking and preference of site and species-specific sources. More recent developments to achieve improved data on allometric equations are not taken into account. For example, the GlobAllomeTree platform was created in 2013 to share and provide access to tree allometric equations. Since then, wood densities, biomass expansion factors, and raw data have been added to the platform. The FAO, CIRAD, and University of Tuscia, and many other organizations all over the world have contributed both their data and expertise. Due to the lack of prioritization towards better sources for allometric equations, the project proponents can potentially choose less accurate sources if they lead to higher calculated emission reductions.

This was found by Haya et al. (2023) who analyzed a sample of avoided deforestation projects using the methodologies VM0006, VM0009, VM0007 and VM0015 and observed that the allometric equations chosen by the project developers resulted in above-ground carbon estimates that were 15.4% higher than the average of their set of best-fit equations. This result suggests that project developers have likely taken advantage of the methodologies' flexibility to choose allometric equations that lead to high estimates of forest carbon and more emission reductions.

The fraction of projects affected by this issue is **unknown**. Where this issue materializes, the degree of overestimation is estimated to be **medium** (up to 30%), given the experiences observed by Haya et al. (2023). The variability in the degree of overestimation among projects is likely to be **high**.

OE13 **Flexibility in determining belowground biomass:** Belowground biomass is usually estimated using root-to-shoot ratios for trees as a relationship between aboveground biomass and roots. Direct measurement is very time-consuming; therefore, methodologies usually apply values from literature and IPCC Guidelines. Root-to-shoot ratios vary with tree species, age, tree size and climate. Therefore, it is important to select a scientific source that is as specific as possible for the forests and trees in the project region.

The guidance in VM0009 explains that the chosen ratio must be suited to the region and vegetation type to which they are to be applied and must be justified by the project proponent through a review of peer-reviewed scientific literature or through supporting field evidence. The flexibility to choose from different sources, with limited guidance on prioritization of data sources and no requirement to use conservative values, poses the risk that project developers pick favorable root-to-shoot ratios that overestimate belowground biomass.

This was observed with the methodologies VM0006, VM0009, VM0007 and VM0015. Haya et al. (2023) compared the choice of root-to-shoot ratios for randomly selected VCS avoided deforestation projects with alternative peer-reviewed methods. On average, the projects' choice of root-to-shoot ratio was 37% higher than the mean of alternatives. They also found ratios applied in projects from literature that were not conservative, but much higher than alternative estimates. This suggests that project developers and verifiers did not conduct a careful comparison with literature sources. Similar to the estimation of aboveground biomass, this result shows that the flexibility provided by the methodologies was used by project developers to determine higher emission reductions.

This issue is likely to affect a **high** fraction of projects. Where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (up to 10%), given that below-ground biomass usually is a smaller part of the overall emission reductions. The variability in the degree of overestimation among projects is likely to be **high**.

OE14 **Overestimation of the carbon fraction in biomass:** The carbon fraction in biomass is the percentage of total dry aboveground biomass that is carbon and is applied to the estimates of aboveground biomass derived from the allometric equations. For tropical trees, Martin et al. (2018) derived a best estimate of 0.456 based on a global synthesis of over 2,000 wood carbon concentration measurements. For tropical woodland trees Ryan et al. (2011) determined, 0.47 as the most appropriate value. This value is also used as a global default value in the 2006 IPCC Guidelines (Volume 4, Chapter 4, Table 4.3). Martin et al. emphasized that the ubiquitous use of 0.5 for carbon fraction introduces a systematic error in forest carbon accounting that leads to an 8.9% overestimate in tropical forests. VM0009 states that literature estimates or direct measurements may be used to determine the carbon fraction. This provides flexibility to project developers to pick a high value and is thus likely to lead to overestimation. This issue is likely to apply to a **high** fraction of projects. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is estimated to be **high**.

We note that projects registered under the methodology commonly failed to disclose key information about forest carbon accounting in their project documents. For instance, the raw tree data and forest inventories compiled by developers are commonly not disclosed. The quantification of carbon stocks cannot be replicated on the basis of the information made available. In our assessment, the lack of transparency and possibility to replicate the emission reduction calculation poses a risk for overestimation, as errors in the calculation or unreasonable assumptions cannot be identified by third parties. In 2022, however, Verra introduced new requirements that suggest that any spreadsheets of emission reduction calculations should be provided (VCS Registration and Issuance Process). Moreover, stakeholders request project documents that are missing from the Verra Registry (VCS Standard). We suggest that the VCS documents could be more specific about the type of data that should be provided (e.g., forest inventories). It would also be useful if the data is shared in a way to assist comparison across projects in public data repositories with standardized metadata and data formats, as well as assigning a citable digital object identifier (DOI) to ease citation tracking.

Determination of leakage emissions

In the following, we first provide an overview of general challenges regarding the determination of leakage emissions. As the VCS methodologies use partially similar approaches to quantify leakage emissions, we then provide an overview of commonalities and differences among the five VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, VM0015 and VM0048). We then turn to a detailed assessment of this methodology.

General challenges in establishing baselines for avoided deforestation projects

The main leakage risk for avoided deforestation projects arises from potential increases in deforestation elsewhere. This may occur due to "activity shifting" or "market leakage". Activity-shifting leakage arises when a deforestation driver is displaced from the project area and leads to deforestation elsewhere. For instance, if timber production is the primary driver, activity leakage occurs if the deforestation agents relocate harvesting from the project area to surrounding areas. Market leakage occurs when avoiding deforestation alters market conditions by reducing the production of a traded commodity relative to the baseline, thereby creating incentives for others to intensify deforestation outside the project area (Streck 2021).

Leakage emissions are methodologically difficult to estimate. Depending on the type of leakage, different ways exist to estimate leakage effects. Activity shifting is often estimated by observing changes in deforestation in areas surrounding the project, which Verra refers to as leakage areas or leakage belts. Measurement tools to quantify such leakage effects can encompass onsite measurement or remote sensing to estimate changes in forest area and carbon stocks, along with interviews conducted within the local community (Henders and Ostwald 2012).

Market leakage is usually estimated with economic models used to determine shifts in the market equilibrium and the subsequent impacts of these changes on leakage (Henders and Ostwald 2012).

The assessment of market leakage presents a distinctive set of difficulties, as it involves evaluating the impact of market forces and the adaptability of regional forest production rates in response to these influences. This undertaking is intricate, time consuming, expensive and it possess challenges in estimation (Guizar-Coutiño et al. 2022; Kuik 2013; Man-Keun et al. 2014). Moreover, models heavily rely on input data and are exceptionally responsive to alterations in the parameters chosen by researchers, introducing a degree of uncertainty (Filewod and McCarney 2023).

Assessing market leakage is also challenging as size of leakage effects can vary significantly. A meta-analysis by (Pan et al. 2020) highlights this complexity, revealing an average leakage rate of 39.6% for forestry projects but with significant variation (from 0 to 75%). This indicates that market leakage effects can be influenced by specific factors like the project location and economic factors integration. Given that leakage can manifest at local, national, or international levels, determining the suitable geographic parameters for its estimation is difficult (Henders & Ostwald 2012).

Market leakage can be very large for avoided deforestation projects. Conservation activities restricting land availability have a high risk of increasing prices for commodities such as timber which can lead to deforestation outside the project's boundary. Filewod and McCarney (2023) summarize that leakage estimates for developed nations are typically at least 70% of reduced output measured in terms of either forestry production or carbon stocks and that lower values (50% or less) have been found in developing country context. The meta-analysis by Pan et al. (2020) reveals an average leakage rate of 39.6% for forestry projects but with significant variation. Research by Atmadja et al. (2022) revealed, 28 out of 62 projects showed leakage effect with rates varying from 1% to 33%. These low leakage rate have been identified as being specific for small countries with rather limited access to timber and capital markets. Filewod and McCarney (2023) and Haya et al. (2023) further emphasize how the global market for wood products and a country's levels of integration into the market can be a significant factor in determining leakage rates.

By contrast, activity leakage may not exhibit higher deforestation rates. A study by Guizar-Coutiño et al. (2022) analyzed activity leakage across 40 VCS-REDD+ projects and found minimal leakage with only 3 projects indicating increased deforestation rates while two actually demonstrated a decrease. Furthermore, Alix-Garcia et al. (2012) reported a 50% reduction in deforestation rates in Mexico with low activity leakage of 4%. These findings suggest that the risk of activity leakage may much smaller than the risk of market leakage.

Summary of commonalities and differences among VCS avoided deforestation methodologies and issues identified in the literature

Quantification methodologies use a variety of approaches to account for leakage. All assessed VCS methodologies account for leakage from activity shifting and market effects, except for VM0015 which only considers leakage from activity shifting. To estimate activity shifting, satellite image analysis is used to detect any increase in deforestation rates in designated leakage zones around the project, often referred to as “leakage belts”. An increase in deforestation rates in these leakage areas must be accounted for through leakage deductions. The methodologies differ in how projects need to establish the geographical boundaries of these leakage areas and how “baseline” deforestation rates in these leakage areas are estimated.

To account for market leakage, the methodologies use default leakage rates. These default leakage rates were specified in the VCS AFOLU requirements which were later integrated in the VCS Methodology Requirements. The rates are 20%, 40%, and 70%, depending on the ratio of the project’s merchantable biomass to total biomass, in comparison to the area to which the displacement occurs. The methodologies differ in how they account for leakage (Haya et al. 2023):

- **Relevant deforestation drivers:** The methodologies differ in which drivers of deforestation are considered relevant for market leakage: VM0006 requires accounting for market leakage only when illegal logging that supplies national or international markets is identified as a deforestation driver. VM0007 requires market leakage deductions when timber, fuelwood, or charcoal production are identified as drivers. VM0009 requires market leakage deductions when any commodity accounted for in the baseline scenario is displaced. VM0015 does not explicitly account for market leakage. VM0048 requires accounting for market leakage when timber, fuelwood, or charcoal are identified as drivers.
- **Application of default values:** The methodologies also differ in how the default values are applied in the quantification of emission reductions. VM0006 applies the leakage deduction to total emissions reductions, whereas VM0007 applies it just to the emissions associated with the displaced timber harvest, and VM0009 applies it to the portion of emissions reductions from aboveground merchantable trees. VM0048 applies the leakage deduction for market leakage to the carbon emissions associated with the timber harvesting in the baseline.
- **Alternative approaches:** VM0009 allows project developers to pursue alternative approaches to quantify leakage emissions with due justification whereas the other methodologies do not allow for such approaches.

Altogether, this suggests that the general VCS requirements for accounting for market leakage have been applied in different ways across methodologies.

Leakage deduction applied by projects appear overall too low. The available evaluations of individual projects using the methodologies VM0006, VM0007, VM0009 and VM0015 suggest that most projects do not apply any leakage deductions. Calyx Global (2023)assessed 70 projects covering 94% of the avoided deforestation credits that have been verified as of December 2022 and found that about 60% of the project claims zero leakage. Similarly, Haya et al. (2023) found that 59% of projects did not take any leakage deductions. Case studies suggest that projects which are at risk of activity or market leakage avoided leakage deductions by using various arguments for exceptions, questionable justifications, and made use of lax requirements in the methodologies).

Where projects apply leakage deductions, these are relatively low. An analysis of 73 projects using the methodologies VM0006, VM0007, VM0009 and VM0015 reveals that the median leakage deduction applied by all projects (including those claiming zero leakage) are 2.6% for activity shifting and 4.4% for market leakage. Zero or low leakage claims are quite prevalent: 55 out of the 73 projects claimed zero leakage from activity shifting and 54 claimed zero market leakage. For those that apply the deduction, total leakage rates are under 25% (Haya et al. 2023). This implies that the projects are likely to underestimate market leakage effects.

Methodologies do not account for international leakage. Any project activities that displace commodities which are linked to the global market can lead to international leakage (Haya et al. 2023). None of the VCS methodologies account for international leakage. However, several studies indicate that a decrease in harvesting of timber or other commodities within project boundary often can induce more harvesting or deforestation in other countries (Gan and McCarl 2007; Murray et al. 2004; Sohngen 2009).

Assessment of VM0009

This methodology estimates the following sources of leakage:

1. **Activity shifting leakage:** This occurs when any deforestation driver is displaced from the project area and leads to deforestation elsewhere. The leakage is quantified using an activity-shifting leakage area and a leakage emissions model. The leakage area refers to an area in which leakage is most likely to be displaced and must be monitored throughout the project's lifetime. The leakage emissions model involves estimating leakage under the condition that project activities are not implemented.

2. **Market leakage:** Market leakage is only considered when any commodity accounted for in the baseline scenario is displaced. The applicability of market leakage depends upon the baseline type.

We identify the following potential sources of overestimation, underestimation or uncertainty with this approach:

OE15 **Uncertainty when determining market leakage discount factor for wood products:** Market leakage due to the displacement of wood production has to be accounted for with a discount factor, which is multiplied with the cumulative baseline emissions from above ground commercial trees. Project developers may choose between three options to estimate the discount factor: 1) they can use a default value of 70%, 2) they can calculate the ratio of merchantable biomass to biomass in a market leakage belt, and may select a corresponding discount factor (ranging from 10% to 70%) in table 6, page 115 of the methodology, 3) they can use peer-reviewed publication, government publication or scientific literature. The possibility to choose from three options gives project developers considerable leeway, as it may allow them to choose an approach that results in low discount factors. The number of projects affect by this issue is estimated to be **high**. The degree of overestimation is unknown. The variability in the degree of overestimation among projects is estimated to be **high**.

OE16 **No accounting for international leakage**: The methodology does not account for any international leakage. International leakage may, however, occur if projects are implemented near the borders of a country or if projects reduce the supply of commodities with globally interconnected markets (e.g., timber or agricultural products). Even if these commodities are used within national boundaries, they could impact the level of imports or exports and thereby lead to international leakage. This can lead to overestimation of emission reductions. The number of projects affected by this issue is **unknown**. The degree of overestimation is **unknown**. The variability in the degree of overestimation among projects is estimated to be **high**.

UE10 **No accounting of any negative leakage:** In principle, it is conceivable that avoided deforestation projects could also reduce deforestation outside the project area. This could occur if the measures taken to address deforestation drivers not only affect the project area but also surrounding areas. The methodology does not account for any such “negative” leakage effects; any decrease in deforestation observed in the leakage belt is not accounted for as a negative leakage term. This could potentially lead to underestimation of total credited emission reductions. The fraction of projects affected, and the degree of underestimation are estimated to be **low**. The variability in the degree of underestimation among projects is likely to be **high**.

OE17 **Flexibility in defining the leakage belt for activity shifting leakage**: In estimating leakage from activity shifting, the methodology allows project developers to define the leakage belt based on specific criteria provided: The leakage belt must be entirely unconverted land, not larger than the project area or, in case of grouped projects, no larger than the geographic area, in the same general region as the project area, but not necessarily adjacent to it. Moreover, it must not include the project area but may overlap with the reference area. Generally, the agents, drivers of conversion and landscape configurations should be similar to the project area. However, the methodology itself states that "the interpretation of the [...] criteria is subjective" (p.233) and asks project developers to choose boundaries for the area that result in a conservative baseline scenario" (p.233) but gives no further guidance on how to ensure conservativeness. This gives project developers the leeway to select an area that underestimates actual leakage from activity shifting. This flexibility likely leads to overestimation. The number of projects affected by this issue is **unknown**. The degree of overestimation is **unknown**. The variability in the degree of overestimation among projects is estimated to be **high**.

Summary and conclusion

Table 2 summarizes the results of the assessment and, where possible, presents the potential impact on the quantification of emission reductions for each of the previously discussed elements.

Table 2 Relevant elements of assessment and qualitative ratings

Element	Fraction of projects affected by this element[2]	Average degree of under- or overestimation where element materializes[3]	Variability among projects where element materializes[4]
Elements likely to contribute to overestimating emission reductions or removals			
OE1: Lack of clarity of definitions and applicability of different parts of the methodology	All	Unknown	Unknown
OE2: Lack of guidance to test significance	Unknown	Low	High

[2] This parameter refers to the likely fraction of individual projects (applying the same methodology) that are affected by this element, considering the potential portfolio of projects. "Low" indicates that the element is estimated to be relevant for less than one third of the projects, "Medium" for one to two thirds of the projects, "High" for more than two third of the projects, and "All" for all of the projects. "Unknown" indicates that no information on the likely fraction of projects affected is available.

[3] This parameter refers to the likely average degree / magnitude to which the element contributes to an over- or underestimation of the total emission reductions or removals for those projects for which this element materializes (i.e., the assessment shall not refer to average over- or underestimation resulting from all projects). "Low" indicates an estimated deviation of the calculated emission reductions or removals by less than 10% from the actual (unknown) emission reductions or removals, "Medium" refers to an estimated deviation of 10 to 30%, and high refers to an estimated deviation larger than 30%. "Unknown" indicates that it is likely that the element contributes to an over- or underestimation (e. g. overestimation of emission reductions in case of an omitted project emission source) but that no information is available on the degree / magnitude of over- or underestimation. Where relevant information is available, the degree of over- or underestimation resulting from the element may be expressed through a percentage range.

[4] This refers to the variability with respect to the element among those projects for which the element materializes. "Low" means that the variability of the relevant element among the projects is at most ±10% based on a 95% confidence interval. For example, an emission factor may be estimated to vary between values from 18 and 22 among projects, with 20 being the mean value. "Medium" refers to a variability of at most ±30%, and "High" of more than ±30%.

Element	Fraction of projects affected by this element[2]	Average degree of under- or overestimation where element materializes[3]	Variability among projects where element materializes[4]
OE3: CO_2 emissions from biomass burning are excluded	Unknown	Unknown	Unknown
OE4: Inclusion of the HWP pool is optional for short- and medium-lived wood products	Unknown	Low	Unknown
OE5: Use of logistic regression to model deforestation	High	High	Unknown
OE6: Flexibility in choosing the start date of the historical reference period	Unknown	Unknown	Unknown
OE7: Flexibility in choosing the reference area	Unknown	High	Unknown
OE8: Lack of appropriate definitions of forest, deforestation and degradation	All	Unknown	High
OE9: Insufficient guidance for ground truthing	High	Unknown	Unknown
OE10: Lack of clarity in determining merchantable trees used for long-lived products	Unknown	Low	High
OE11: Lack of binding character of essential parts of the methodology	Unknown	Unknown	Unknown
OE12: Flexibility in choosing allometric equations	Unknown	Medium	High
OE13: Flexibility in determining belowground biomass	High	Low	High
OE14: Overestimation of the carbon fraction in biomass	High	Low	High
OE15: Uncertainty when determining market leakage discount factor for wood products	High	Unknown	High
OE16: No accounting for international leakage	Unknown	Unknown	High
OE17: Flexibility in defining the leakage belt for activity shifting leakage	Unknown	Unknown	High

Element	Fraction of projects affected by this element[2]	Average degree of under- or overestimation where element materializes[3]	Variability among projects where element materializes[4]
Elements likely to contribute to underestimating emission reductions or removals			
UE1: Aboveground merchantable tree biomass is optional	Unknown	Low	High
UE2: Above ground non-tree biomass is optional to include in the project's forest carbon stocks	Unknown	Low	Unknown
UE3: Belowground tree biomass is identified as an optional pool	Unknown	Low	Unknown
UE4: Deadwood is an optional pool for some projects	Unknown	Low	Unknown
UE5: Litter carbon pool is excluded	All	Low	Unknown
UE6: Soil carbon is identified as an optional source	Unknown	Low	Unknown
UE7: Methodology excludes CH_4 emissions from livestock in baseline scenario	Unknown	Low	Unknown
UE8: N_2O emissions from the application of fertilizer may be excluded	Unknown	Low	Unknown
UE9: Exclusion of emissions and removals related to logging	All (avoided planned deforestation projects)	Low	Unknown
UE10: No accounting of any negative leakage	Low	Low	High
Elements with unknown impact			
Un1: Emissions of CH_4 and N_2O from biomass burning are excluded	Unknown	Low	Unknown
Un2: No consideration of CO_2 emissions from fossil fuels	Unknown	Low	Unknown
Un3: Flexibility in choosing the proxy area	Unknown	Medium	Unknown
Un4: It is optional to determine a minimum sample size for sample points in the reference area	Unknown	Medium	Unknown
Un5: Insufficient guidance for determining co-variates in the fitting of the biomass emission model	Unknown	High	Unknown

Element	Fraction of projects affected by this element[2]	Average degree of under- or overestimation where element materializes[3]	Variability among projects where element materializes[4]
Un6: Overall uncertainty assessment	All	Unknown	Unknown
Un7: Outdated methodological basis	All	Unknown	Unknown
Un8: Specific guidance missing for remote sensing	High	Unknown	Unknown
Un9: Insufficient guidance on forest stratification	All	Unknown	Unknown
Un10: Outdated guidance on harvested wood products	All	Unknown	Unknown

The table shows that there are many potential sources of overestimation, underestimation, and uncertainty. Based on our assessment of the elements in the table, we conclude that the methodology is likely to lead to overestimation of emission reductions or removals and that the degree of overestimation is likely to be large (i.e., larger than 30%). This corresponds to a score of 1 according to the CCQI methodology (see page 2).

In our assessment, overestimation of baseline deforestation rates is the largest integrity risk. In this methodology the most important issues likely leading to an overestimation of baseline emissions are the use of a logistic regression to model deforestation (OE5) and the flexibility provided for choosing a reference area (OE7). Moreover, establishing the baseline is associated with very large uncertainty. In our assessment, the largest contributor to uncertainty is the lack of sufficient guidance for choosing covariates in the logistic regression (Un5).

We also find that leakage effects are likely to be underestimated, in particular with regard to the market leakage discount factor for wood products (OE15) and flexibility in defining the leakage belt (OE17). Like other Verra methodologies, the methodology also does not account for international leakage (OE19). Lastly, there is a large risk that biomass carbon stocks are overestimated, partially due to the use of outdated data and partially due to the flexibility provided to project developers in determining carbon stocks (OE12 to OE14). The flexibility in selecting the areas to measure residual carbon stocks after deforestation may contribute to uncertainty (Un3). We also note that the exclusion of some carbon pools and emission sources may lead to underestimation for some projects (UE1 to UE9) but this underestimation is estimated to be significantly smaller than the risks of overestimation.

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