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**
Quantification methodology:	**VCS Methodology VM0015, Version 1.2** **Methodology for Avoided Unplanned Deforestation**
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 VM0015. Methodology for Avoided Unplanned Deforestation. Version 1.2, 18 December 2023. https://verra.org/methodologies/vm0015-methodology-for-avoided-unplanned-deforestation-v1-2/

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 type:

- **Avoiding 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 type, as described above, is applicable to the methodology. The methodology is applicable in large landscapes of undisturbed forest (frontier) and in mosaic landscapes of forest and other land use types.

Selection of emission sources for calculating emission reductions or removals

The methodology states that “Carbon pools that are expected to decrease their stocks in the project scenario compared to the baseline must be included where their exclusion leads to a significant overestimation of the net GHG emission reductions generated during the baseline validity period. Where a carbon pool is included in the baseline accounting, it must also be included in project scenario and leakage accounting” (p. 23, section 5.3). It is also required that if the exclusion of a carbon pool is not conservative, project proponents have to demonstrate that the exclusion will not lead to a significant overestimation of the net anthropogenic GHG emission reduction. “Any decrease in carbon stock or increase in GHG emissions attributed to the project activity must be accounted where significant, otherwise it may be neglected” (p. 5, section 2).

If the exclusion is significant, the pool must be included. It further states that "[t]he significance of pools must be determined (…) Appendix 2 should be used to test significance of pools" (p. 23, section 5.3). Thus there is a clear methodology to determine insignificant emission sources.

The drivers of deforestation considered by this methodology include a broad spectrum, including conversion for agriculture, encroaching roads, settlement, and logging. The implications of including or excluding carbon pools and emission sources depend on the post-deforestation land uses predicted to occur in the baseline. If agriculture is the driver of deforestation, the land use following deforestation is likely to be agriculture. The patterns of agricultural use may differ by region. The land may be continuously used for agriculture, such as when palm oil plantations are established (e.g., in Indonesia) or if pastures are established following a period of crop cultivation (e.g., in Brazil). The land use may also be cyclical where a period of agricultural use is followed by a fallow period in which secondary forest may grow back (e.g., in the Democratic Republic of Congo). Following the fallow period, the area is often again cleared of its forest cover and cultivated, at the landscape level, which creates a mosaic of fallow, secondary forest of different ages, and agricultural fields. How much carbon is stored in the landscape (i.e., in trees, other vegetation and soils) depends on the length of the fallow period. For this assessment, we consider the settlement driver to coincide with the agriculture driver as both drivers typically occur. If logging is the initial driver of deforestation, trees would be harvested and removed, and non-tree biomass may be damaged but would not be targeted for removal. The initial effect of logging is a degradation of the forest carbon stock, since usually the largest and more valuable trees are removed first. However, agriculture is often a secondary driver of deforestation, since the infrastructure created for logging increases access to forests and harvesting helps to prepare the land for agriculture. This is assumed to be the case for the development or expansion of roads as well. For these reasons, we assume for our analysis that ultimately the dominant post-deforestation land use is agriculture. We thus assume deforestation in the baseline scenario would in the long-term result in agriculture on these lands.

The methodology specifies mandatory and optional carbon pools and sources of emissions and excludes certain pools and 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	Mandatory	Major carbon pool affected by project activities.
Aboveground non-tree biomass	Mandatory if baseline land cover is a perennial crop. Optional for other baseline land cover.	Major carbon pool affected by project activities. In the baseline scenario, non-tree biomass such as shrubs are likely to be removed. Therefore, exclusion of this pool in the baseline and the project scenario is likely to be conservative. Given that inclusion in the baseline and project scenario are both optional (if the baseline is not perennial crops), project developers can decide to include this pool.
Belowground biomass (this includes both tree and non-tree biomass)	Optional	Belowground tree biomass is a primary source of emission reductions from the project activity. Exclusion of this pool in the baseline and project scenario would likely be conservative.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
		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	Mandatory if greater in the baseline than the project scenario, when significant. Optional in other circumstances.	Major carbon pool affected by project activities. In the baseline scenario, slash deadwood would result from harvesting (which does not occur to the same degree in the project) but when the land use shifts to agriculture, deadwood would be burned or removed. The implementation of the avoided deforestation projects is likely to result in more naturally occurring deadwood than in the baseline. Therefore, exclusion of deadwood in the project and baseline scenario is likely to be conservative.
Litter	Optional	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 when forests are converted to cropland in the baseline. Excluded when forest is converted to grazing lands and perennial crop lands in the baseline.	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.
Organic soils	Not addressed	Peat soils are not eligible for project development under VM0015, but organic soils are not mentioned. Forested wetlands and mangrove forests, which are likely to constitute organic soils, are eligible to apply VM0015. VM0015 uses a much higher threshold for peat of 65% organic matter compared to the 20-30% threshold identified by IPCC Guidelines for organic soils and there is no separate treatment for organic soils in VM0015. Thus, organic soils are treated the same as mineral soils by VM0015 and measured through the SOC pool (see above).
Harvested Wood Products (HWP)	Included if the baseline would result in significantly more carbon stored in long-term wood products	Timber harvest/logging 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

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
	or if the pool is included in the project scenario quantification. Optional in other circumstances.	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 provisions of the methodology are interpreted to mean that if HWP does not result in significantly more carbon stored in long-term wood products in the baseline (e.g., the baseline only results in significantly more medium-term wood products) then the pool is optional and may be excluded. This is generally appropriate, but the provision is limited to long-lived products, which could lead to overestimation for short- and medium-lived products.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Emission sources		
Emissions from biomass burning	CO_2 excluded from project scenario	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 from accounting. Exclusion of this source from the project scenario can therefore lead to overestimation.
	CH_4 and N_2O unclear	The methodology identifies in Table 3 that CH_4 is TBD (typically treated as optional) and N_2O is excluded as it is considered insignificant. But the methodology on page 26 identifies that "where non-CO_2 emissions from forest fires used to clear forests are counted in the baseline, they must also be counted in the estimation of activity displacement leakage." These provisions conflict and may therefore allow a project developer to favorably interpret and include or exclude the source, whatever is more beneficial in the context of the project. Furthermore, optional inclusion and/or exclusion assumes that higher emissions from fires 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 of CO_2 from the combustion of fossil fuels	Excluded from project scenario	Emissions of CO_2 from the combustion of fossil fuels may occur in the baseline related to harvesting and agriculture, or in the project related to monitoring and patrolling, it is uncertain whether CO_2 emissions from the combustion of fossil fuels decrease or increase as a result of the implementation of the project. Therefore, it is uncertain how exclusion of this source may affect calculated emission reductions. Non-CO_2 emissions from the combustion of fossil fuels are considered insignificant.
N_2O emissions – from enrichment planting and increased agricultural fertilizer use	Excluded	The methodology in section 8.3.1.1 states that "N_2O emissions from nitrogen fertilization are considered always insignificant according to the most recent version of the VCS Standard" (p. 105). But they may be significant when the project includes fertilizer education and promotion as one of its leakage prevention measures. Exclusion in the project scenario, where fertilizer use does not increase compared to the baseline is appropriate and conservative. When fertilizer use increases, due to project activities like enrichment planting or sustainable intensification of agriculture on existing agricultural land, exclusion can lead to overestimation.

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Livestock emissions	CH_4 and N_2O optional	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.

OE1 **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**.

OE2 **N_2O emissions from increased fertilizer use are excluded:** When fertilizer use increases due to project activities like enrichment planting or sustainable intensification of agriculture on existing agricultural land, emissions of N_2O will increase. Therefore, exclusion of this emission source 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**.

OE3 **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 **Inclusion of aboveground non-tree biomass is optional**: In the baseline, deforestation would result in a lower amount of non-tree biomass than in the project. The exclusion of this pool would thus lead to underestimation of emission reductions. This issue applies to projects that opt to exclude aboveground 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**.

UE2 **Inclusion of belowground biomass is optional**: In the baseline scenario, deforestation would result in a lower amount of tree biomass than in the project scenario and the belowground biomass directly corresponds to the aboveground biomass. The exclusion of this pool would thus lead to underestimation of emission reductions compared to the baseline scenario. Belowground non-tree biomass could either decrease or increase due to the implementation of the project; however, these effects are deemed to be small. This issue applies to projects that opt to exclude belowground 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**.

UE3 **Deadwood is an optional source, when the baseline deadwood is less than project deadwood**: Naturally occurring deadwood is likely to be lower in the baseline scenario than in 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 deadwood. 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 **Litter is identified as an optional source:** Litter is anticipated to be lower in the baseline scenario than in 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 litter. 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**.

UE5 **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**.

Un1 **Methodology does not consider emissions of CO_2 from the combustion of fossil fuels**: Given that CO_2 emissions from the combustion of fossil fuels may occur in the baseline related to harvesting and agriculture, or in the project 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 emission reductions. The variability in the degree of uncertainty among projects is **unknown**.

Un2 **Optional inclusion and/or exclusion of CH_4 and N_2O emissions from biomass burning:** The methodology is unclear regarding the inclusion or exclusion of CH_4 and N_2O emissions from biomass burning. We assume that CH_4 emissions are treated as an optional emission source and N_2O emissions are excluded. 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**.

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.

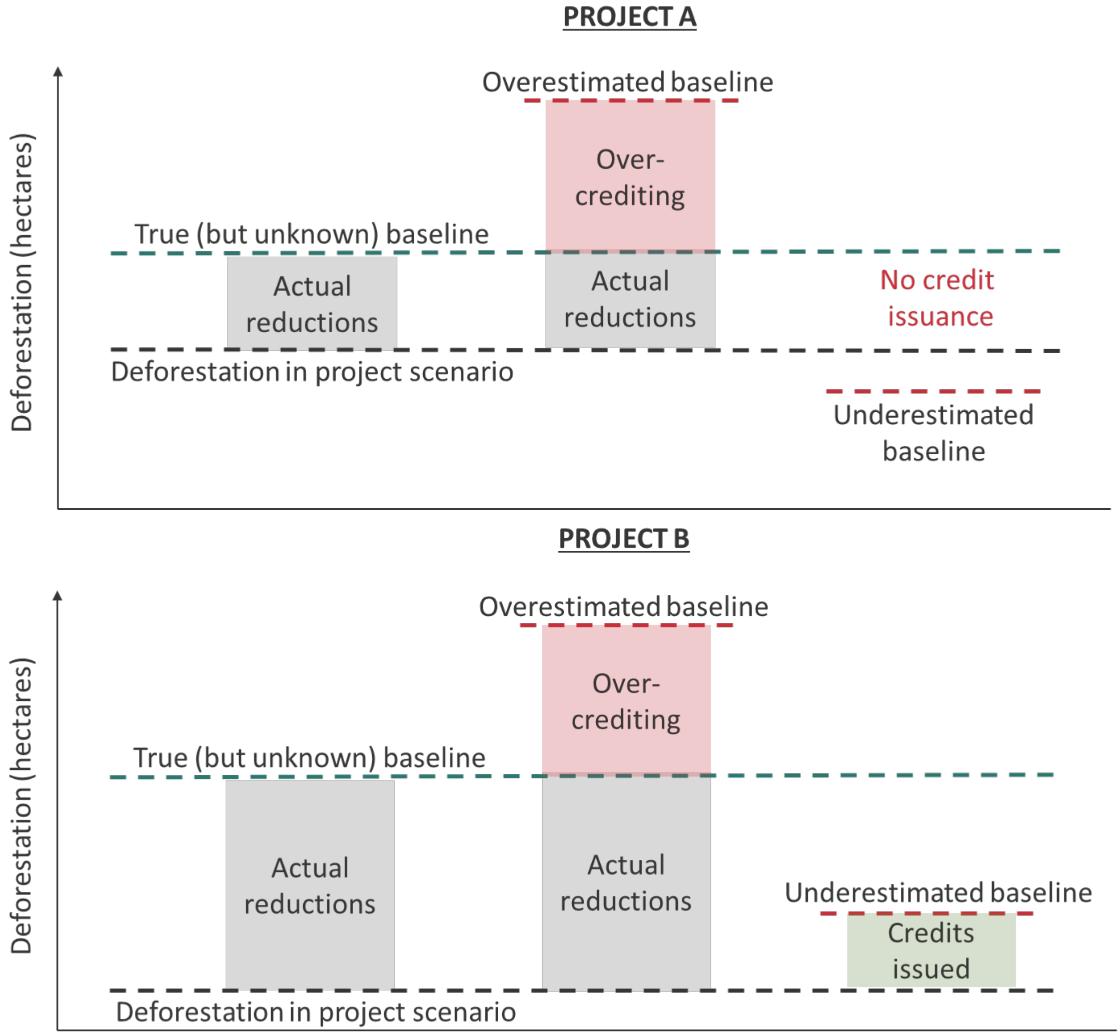
General challenges in establishing baselines for avoided deforestation projects

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.

Figure 1 Implications of uncertainty in baseline deforestation levels



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.

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).

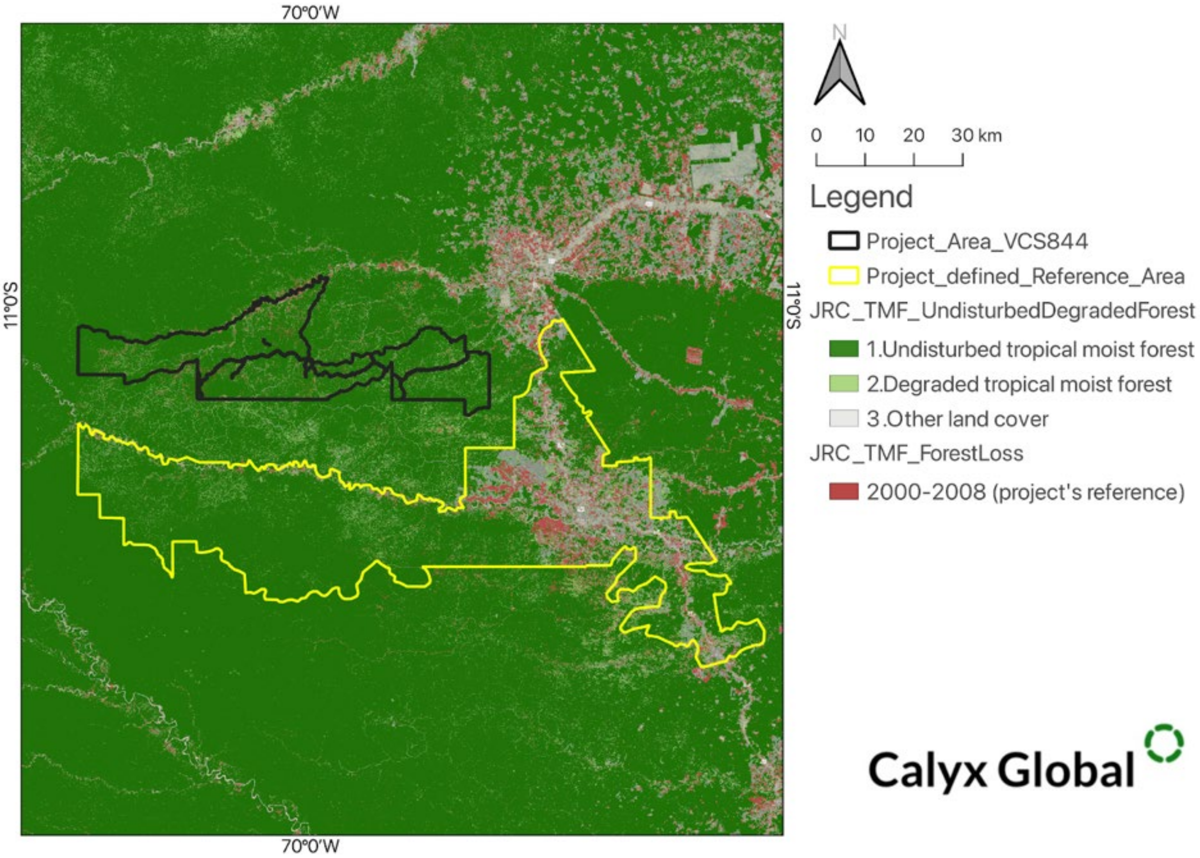
Flexibility in establishing baseline deforestation rates. The four older VCS methodologies (VM0005, VM0007, VM0009 and VM0015) provide considerable flexibility on how to establish baseline deforestation rates. This allows project developers to make subjective choices that can lead to higher baselines (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 VM0015

This methodology uses a reference region to determine past deforestation rates in a historical reference period, its associated drivers and the patterns of "land use and land cover change". Past forest cover and forest cover changes are assessed based on at least three historical forest cover maps of the reference region, representing the start, middle and end of the historical reference period. This information is used to make an estimate of expected future deforestation. The methodology also uses a spatial analysis to determine the location of future deforestation. The expected future deforestation and carbon estimates in the reference region are then used to calculate baseline emissions. The baseline validity period is six years, after which the baseline must be reassessed (VCS Standard v4.6 and v4.7).

The reference region encompasses the project area, leakage belt and areas for addressing leakage. It can be stratified to improve accuracy of assessments. Stratification criteria are for example different deforestation rates, or agents of deforestation, if they are spatially correlated, or to reflect a chronological sequence of deforestation in case of infrastructure development. The project area must have been covered by forest for at least the 10 years prior to the project start date.

The most plausible baseline scenario is determined using VT0001 for the assessment of project additionality. Once the most likely scenario is identified, an analysis of "agents, proximate causes, drivers and underlying causes of deforestation" is required. This analysis serves as an input for the estimation of the quantity and location of future deforestation. The following activities must be included in the baseline scenario of deforestation: planned or unplanned logging for timber, fuel-wood collection, charcoal production, agriculture or grazing activities.

The methodology provides two approaches for projecting future deforestation: 1) The historical annual average deforestation rate observed during the historical reference period is assumed to continue in the future or 2) the historical trend is extrapolated as a function of time using a simple linear regression. The methodology allows to use a combination of the two approaches for different strata of the reference region. The use of approach 2 requires a 10-year annual deforestation time series. Which approach is used depends on whether the analysis of past deforestation and drivers reveals a trend supported by "conclusive evidence". The analysis of agents and drivers of deforestation must be repeated until conclusive evidence of the presence or absence of a trend is found. Approach 1 must be used when there is no trend in the historical deforestation rates or when the trend is relatively constant. Approach 2 must be used when the trend in historical deforestation is decreasing or increasing. If no conclusive evidence for an increasing trend is found, approach 1 must be used. In case of an increasing deforestation trend, approach 2 also requires that the availability of land at risk of deforestation is considered "to avoid non-conservative projections of baseline deforestation". This is done by identifying biophysical and socio-economic constraints that may limit the activities of agents of deforestation and by determining thresholds under which deforestation by the agents either occurs or not. Using this information, the forest area available for potential future deforestation is determined (Maximum Potential Deforestation Map). The area is further stratified into three "suitability classes" (optimal, average, sub-optimal), according to whether the conditions of the forest (e.g., slope, humidity, soil type) make it suitable for the other land uses intended by the agents of deforestation.

Once the area of potential future deforestation is determined, a deforestation risk map is produced to determine the likely location of future deforestation and for allocating likely future deforestation to the project area located within the reference region. Deforestation risk mapping requires identifying the spatial variables that most likely drive deforestation and overlaying them with the forest cover map. The methodology requires the production of multiple risk maps in order to allow for a quality assessment.

The final steps after allocation of future deforestation to the project area are to determine the likely post-deforestation land use to the deforested area and to determine the carbon stocks for each forest class and post-deforestation land use class. Carbon stocks can be measured in the field or derived from literature.

OE4 **Flexibilities in the selection of the reference region**: Unlike other methodologies, VM0015 requires that the project area is located within the reference region. The reference region and the project area must have similar conditions that determine deforestation risk. The methodology establishes criteria for ensuring similarity in the deforestation risk between the reference region and the project area. These include the agents and drivers of deforestation, landscape and ecological conditions, land tenure and land use conditions, as well as policies and regulations. During the 10-years before the project start, the reference region must have similar agents, drivers and patterns of deforestation as expected in the project area at project start date. However, the criteria provide a degree of flexibility in the level of similarity. For example:

- A rule of thumb is provided for the size of the reference region, depending on the size of the project area (see page 17). Project areas below 100.000 ha must have a reference region that is 20 to 40 times larger and project areas at or above 100.000 ha must have a reference region that is 5 to 7 times larger than the project area. These values are derived from a model comparison study for estimating baseline emissions in six different regions (Brown et al. 2007). The original paper provides different area thresholds than the methodology, as the smaller magnitude of the reference region applies to projects of "several hundreds of thousand ha". It also indicates that regional conditions are relevant for determining the relative size of the reference region to the project area, which is not considered by the methodology.

- The methodology requires that the boundaries of the reference region are unbiased and "coincide with a combination of natural and administrative boundaries". Arbitrary exclusion of forests and inclusion of areas with high deforestation should not occur. However, this does not preclude discretionary choices for a reference region and the only requirement related to boundaries is that the rationale behind the choice must be described in the project document.

- Settlement density (settlements/km2), road density (m/km2) and river density (m/km2) in the reference region at the start of the historical reference period can be the same, or less or can exceed (no more than 20%) than the density surrounding the project area. Given that access to forest is one of the key determinants of deforestation risk, there may be large differences between a reference region that has a lower density than the project area and one that has a higher density.

- Project proponents are required to "demonstrate, using verifiable data, that the conditions determining the likelihood of deforestation within the project area are similar, or expected to become similar, to those found in the reference region". The latter case, where conditions are expected to become similar, adds an additional level of uncertainty to the baseline scenario. Even if verifiable information is provided, the future development is still a guess and may not come to pass. Also, no timeline is provided for when conditions are expected to become similar.

Overall, the provisions in the methodology thus provide considerable flexibility to project developers in defining the reference region. This creates the risk that project developers select a reference region with higher deforestation than is likely to occur in the project. Arbitrary selection of reference regions was indeed identified as a major source of overestimation of emission reductions (see, for example, Calyx Global 2023; Haya et al. 2023).

The number of projects affected by this issue is **unknown** but could likely be high because project proponents have an implicit incentive to choose reference regions that indicate higher levels of historical deforestation. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **high** (larger than 30%). The variability in the degree of overestimation among those projects for which the issue materializes is **unknown**.

OE5 **Flexibility in choosing the length of the historical reference period:** The methodology requires to set a start and end date for the historical reference period. The start date must be within 10 years before the project start date and the end date "as close as possible to the project start date". Even though the availability of imagery for assessing land cover is a determining factor for historical analysis, this flexibility may result in arbitrary choices for the length of the historical reference period. Project developers have incentives to select the period in a manner that results in higher deforestation rates in reference region. The number of projects affected by this issue is **unknown** but could likely be high because project proponents have an implicit incentive to choose a period that results in higher levels of historical deforestation. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **medium to high** (larger than 10%). The variability in the degree of overestimation among those projects for which the issue materializes is **unknown**.

UE6 **Discounting for uncertainty in the area estimates of land cover and land use change:** An accuracy assessment of the classification of land uses and land covers and related area estimates from historical maps is required by the methodology. The uncertainty of mean area estimates is the "sampling error as a two-sided 90% confidence interval. A discount to the area estimate is applied if the uncertainty is above 10% and below 20%. This could potentially lead to underestimation of total credited emission reductions. The number of projects affected is **unknown**. Where this issue materializes (i.e., the uncertainty is larger than 10% and an uncertainty deduction is applied), the applied discount is between 10% and 20%, and the degree of underestimation thus **medium**. The variability in the degree of underestimation among projects is **unknown**.

Un3 **Potential for combining approaches for projecting baseline deforestation:** The methodology provides two approaches for projecting future deforestation and allows to use a combination of the two approaches for different strata of one reference region. Which approach must be used, depends on whether there is a trend in the historical deforestation supported by "conclusive evidence". Also, approach 2 requires a 10-year time series of imagery. A combination of approaches could deliver more accurate baseline estimates for specific strata, but it also makes baseline assessment by third parties more complex. They would need to assess the quality of stratification, the accuracy of the historical deforestation analysis, the evidence to support any identified trend, whether the correct baseline approach is chosen, and the maximum potential deforestation risk map, for each stratum. This provides multiple instances where errors may occur. The number of projects affected is **unknown**. The added level of complexity associated with combining baseline approaches during project development could act as a deterrent for combining approaches. While there could be cases where it is necessary due to data availability or there could be an incentive to combine approaches if it is possible from early on to identify strata where approach 2 leads to higher baseline emissions than approach 1. Where the issue materializes, the degree of uncertainty to the estimation of total credited emission reductions is **unknown**. The variability among those projects for which the issue materializes is **unknown**.

OE6 **Flexibility in determining the areas of optimal deforestation and the areas of average deforestation:** In case the historic deforestation rate shows an increasing trend, and a linear regression is used to project future deforestation, the methodology requires that the available land for deforestation be considered as a limiting factor. To do so, project proponents are expected to determine the available forest area suitable for deforestation. This is done according to the agents of deforestation and the expected post-deforestation land uses. Thresholds must be determined for what constitute areas suitable for optimal use for an agent and land use, what constitutes areas suitable for average use and what constitutes areas for sub-optimal use. Little guidance is provided for how to set these thresholds or how to implement the approach conservatively. Information asymmetry may make it difficult to assess the quality of the analysis and project proponents may have an incentive to determine thresholds that increase the area suitable for optimal use, which would increase the area of baseline deforestation. This issue applies to all projects that use baseline approach 2. This share is **unknown**. The impact on total credited emission reductions is **unknown** but could be potentially high. The variability among those projects for which the issue materializes is **unknown**.

OE7 **Flexibility in choosing the modelling approach for deforestation risk mapping:** The methodology explicitly allows the use of any deforestation risk mapping model or algorithm if it is peer-reviewed and in line with the methodology. It mentions the following available models: Geomod, TerrSet, Dinamica EGO, CLUE and Land Change Modeler. The methodology requires the preparation of several risk maps, each using different spatial driving variables for deforestation and assumptions, to allow for a comparison and selection of the "most accurate map". The methodology does not require that different risk mapping models be compared. Therefore, it asks for a comparison of different outcomes from one model, but not for a comparison from different models. It also does not address the uncertainty associated with such modeling and does not require to use a conservative approach. However, as shown by Haya et al (2023), different risk map models can deliver significantly different results when it comes to allocating deforestation risk and a lack of model validation by Verra "creates a perverse incentive for developers to cherry-pick risk-map algorithms that financially benefit them". This issue is likely to apply a to **high** fraction of projects. The impact on total credited emission reductions is estimated to be **high** (larger than 30%). The variability in the degree of overestimation among those projects for which the issue materializes is **unknown**.

Quantification of carbon stocks in the project and the baseline scenario

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:** The methodology requires to use the forest definition adopted by the country under the Kyoto Protocol or the one used in the GHG inventory. However, the national forest definition is not necessarily useful at project level to detect deforestation and degradation. 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.

For example, a national inventory may use a 10% canopy cover threshold because the country has dry forests that are less dense, and the national forests should include these dry forests. 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. This source, for example, shows that it is important to distinguish between natural and planted forests. In VM0015 "forests" can be natural, seminatural, or anthropogenic and they may include primary or old-growth forests (intact or logged), secondary forests, planted forests, agro-forestry and silvo-pastoral systems" (p. 124). This lack of clear and unambiguous forest definition introduces high uncertainties for the estimation of the area 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**.

Un4 **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**.

Un5 **Outdated methodological basis:** The methodology refers to the following IPCC methodologies; Revised IPCC 1996 GL LULUCF for biomass burning, IPCC Good Practice Guidance for LULUCF (2003) and to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. There are three relevant updated methodology reports published by the IPCC that are not used in the methodology:

- 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. VM0015 is unnecessarily leading to higher uncertainties in the estimation due to the references to outdated default parameters. Remote sensing methods and data availability has been developed tremendously since 2006. This is reflected in the subsequent IPCC methodology reports but ignored by VM0015. The methods also used outdated GWP values for CH_4 (21) and N_2O (310) (p. 82). VM0015 refers to the GOFC-GOLD sourcebook for REDD in many parts of the estimation which is useful because this source provides more specific guidance for REDD projects and in particular related to the identification of deforestation and degradation through remote-sensing data. However, the GOFC-GOLD sourcebook is a compilation of methodologies how the estimation can be done and does not provide any mandatory guidance, thus while the reference is useful, it offers substantial flexibility for project proponents. 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**.

Un6 **Emissions from organic soils on forested wetlands and mangrove forests:** VM0015 includes forested wetlands and mangrove forests. Peat is excluded and defined in the methodology as organic soils with at least 65% organic matter and a minimum thickness of 50 cm (p. 6). This definition is inconsistent with the definition of organic soils in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and FAO criteria where organic soils are defined with a thickness of an organic horizon greater than or equal to 10 cm and where soils subject to water saturation episodes shall have either at least 12% organic carbon by weight (about 20% organic matter) if the soil has no clay or at least 18% organic carbon by weight (about 30% organic matter) if the soil has 60% or more clay. Soils that are not saturated with water for more than a few days must contain more than 20% organic carbon by weight (about 35% organic matter). Peat is not defined in IPCC Guidelines, but peat soils and organic soils are often used in a similar way in common language. VM0015 uses much higher thresholds for peat of 65% organic matter compared to 20-30% and thickness of 50 cm compared to 10 cm in IPCC Guidelines. Thus, organic soils are not treated as organic soils, but as mineral soils and can be excluded from the accounting of emissions in many cases because soil carbon pools can be excluded from project emissions for all forest conversions apart from conversions to cropland. The CO_2, CH_4 and N_2O emissions from the conversion of forested wetlands on organic soils that meet the IPCC definitions (but not the project definitions) are not adequately estimated by the methodology, but it is stated that the methodology is applicable. This issue introduces uncertainty. The fraction of projects affected by this issue, the level of uncertainty, and the variability among projects are **unknown**.

Un7 **Specific guidance missing for remote sensing:** The methodology does not provide specific guidance related to the use of satellite data and remote sensing methods or related to the quality assurance of data derived from remote sensing but refers to the GOFC-Gold Sourcebook for REDD (Achard et al. 2016). Among the older VCS methodologies for avoided deforestation, VM0015 provides the most detailed guidance related to the use of remote sensing data. However, 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. The drastic improvements in remote sensing data for forest monitoring are not reflected in the methodology. It is essential to update and provide more specific guidance based on the latest science available to improve accuracy. The method specifies that the minimum classification accuracy of each class or category in the Land-Use and Land-Cover Map and Land-Use and Land-Cover Change Map, respectively should be 80% (p. 36). This value should be checked whether it should be updated due to technological progress and higher accuracy achieved.

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**.

OE9 **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).

VM0015 specifies that the allometric equations are preferably local-derived and forest type-specific. "When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of IPCC GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area (or within the forest class), but outside the sample plots, a few trees of different species and sizes and estimate their biomass and then compare against the selected equation is the most prescriptive, preferring locally derived and forest-type-specific equations but allowing generic equations if they are conservative" (p. 141). In this aspect, VM0015 is better than VM0006 or VM0009 because it provides a clear ranking and preference of site- and species-specific sources and additional verification is necessary for general allometric equations from literature. However, 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.

Overall, we see some risk that project proponents can potentially choose less accurate sources on allometric equations if they lead to higher calculated emission reductions; however, the risk is deemed lower than for the methodologies VM0006, VM0007 and VM0009. The fraction of projects affected by this issue is **unknown**. Where this issue materializes, the degree of overestimation is estimated to be **low** (up to 10%), due to the more stringent provisions as compared to the methodologies. The variability in the degree of overestimation among projects is likely to be **high**.

OE10 **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 VM0015 is flexible and mentions local regression equations, the national inventory, IPCC Guidelines and published sources and that it is desirable to use age-dependent or stand density-dependent equations (p. 144). 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**.

OE11 **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 the carbon fraction introduces a systematic error in forest carbon accounting that leads to an 8.9% overestimate in tropical forests. VM0015 requires using a value measured or estimated from literature and does not provide specific guidance on the selection of 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 VM0015

The methodology estimates the following sources of leakage:

1. **Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention measures:** This involves assessing emissions from leakage prevention measures when significant. The methodology identifies carbon stock changes due to activities implemented in leakage management areas and methane and nitrous oxide emissions from grazing animals as mitigation measures that can result in a significant decrease in carbon stocks and an increase in GHG emissions.

2. **Decrease in carbon stocks and increase in GHG emissions associated with activity displacement leakage:** This type of leakage occurs when deforestation activities, intended to be reduced within the project area, unintentionally shift to outside the project area. If the decrease in carbon stocks in the leakage belt area exceeds what was expected at the baseline, it indicates that activity displacement leakage has occurred.

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

OE12 **No accounting for market leakage:** The methodology fails to account for market leakage. It is highly unlikely that there is no market leakage from projects registered under this methodology, as project activities might reduce the production of traded commodities relative to the baseline. This is likely to lead to a underestimation of leakage and overestimation of total credited emission reductions. This issue is likely to affect **all** projects. The degree of overestimation is **unknown**. We estimate that the variability in the degree of overestimation among projects is **high**.

UE7 **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**.

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[1]	Average degree of under- or overestimation where element materializes[2]	Variability among projects where element materializes[3]
Elements likely to contribute to overestimating emission reductions or removals			
OE1: CO_2 emissions from biomass burning are excluded	Unknown	Unknown	Unknown
OE2: N_2O emissions from increased fertilizer use are excluded	Unknown	Unknown	Unknown
OE3: Inclusion of the HWP pool is optional for short- and medium-lived wood products	Unknown	Low	Unknown

[1] 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.

[2] 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.

[3] 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%.

OE4: Flexibilities in the selection of the reference region	Unknown	High	Unknown
OE5: Flexibility in choosing the length of the historical reference period	Unknown	Medium to High	Unknown
OE6: Flexibility in determining the areas of optimal deforestation and the areas of average deforestation	All (projects that use baseline approach 2)	Unknown	Unknown
OE7: Flexibility in choosing the modelling approach for deforestation risk mapping	High	High	Unknown
OE8: Lack of appropriate definitions of forest, deforestation and degradation	All	Unknown	High
OE9: Flexibility in choosing allometric equations	Unknown	Low	High
OE10: Flexibility in determining belowground biomass	High	Low	High
OE11: Overestimation of the carbon fraction in biomass	High	Low	High
OE12: No accounting for market leakage	All	Unknown	High
Elements likely to contribute to underestimating emission reductions or removals			
UE1: Inclusion of aboveground non-tree biomass is optional	Unknown	Low	Unknown
UE2: Inclusion of belowground biomass is optional	Unknown	Low	Unknown
UE3: Deadwood is an optional source, when the baseline deadwood is less than project deadwood	Unknown	Low	Unknown
UE4: Litter is identified as an optional source	Unknown	Low	Unknown
UE5: Soil carbon is identified as an optional source	Unknown	Low	Unknown
UE6: Discounting for uncertainty in the area estimates of land cover and land use change	Unknown	Medium	Unknown
UE7: No accounting of any negative leakage	Low	Low	High

Elements with unknown impact			
Un1: Methodology does not consider emissions of CO_2 from the combustion of fossil fuels	Unknown	Low	Unknown
Un2: Optional inclusion and/or exclusion of CH_4 and N_2O emissions from biomass burning	Unknown	Low	Unknown
Un3: Potential for combining approaches for projecting baseline deforestation	Unknown	Unknown	Unknown
Un4: Overall uncertainty assessment	All	Unknown	Unknown
Un5: Outdated methodological basis	All	Unknown	Unknown
Un6: Emissions from organic soils on forested wetlands and mangrove forests	Unknown	Unknown	Unknown
Un7: Specific guidance missing for remote sensing	High	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. The flexibility provided by the methodology for selecting the reference region (OE4) and choosing the length of the historical reference period (OE5), and for selecting the modelling approach for deforestation risk mapping (OE7) are the most important issues that contribute to a likely overestimation of expected deforestation in the baseline. A factor contributing to uncertainty in the estimated baseline emissions and adding complexity to the assessment of baselines is the possibility to use different baseline approaches for different forest strata in one project (Un3). The methodology requires project proponents to apply discounts according to the accuracy achieved in the identification of land cover and land-use change (UE6), which can contribute to some underestimation.

We also find that leakage effects are likely to be underestimated because market leakage is not accounted for (OE12). 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 (OE9 to OE11). We also note that the exclusion of some carbon pools and emission sources may lead to underestimation for some projects (UE1 to UE5) but this underestimation is estimated to be significantly smaller than the risks of overestimation.

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