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 types:	**Avoided unplanned deforestation** **Avoided planned deforestation**
Quantification methodology:	**VCS Methodology VM0007, Version 1.7** **REDD+ Methodology Framework (REDD+MF)**
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 VM0007. REDD+ Methodology Framework (REDD+MF). Version 1.7 of 27 November 2023. https://verra.org/methodologies/vm0007-redd-methodology-framework-redd-mf-v1-7/

2 Verra (2023): VCS Module VMD0001. Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools (CP-AB). Version 1.2, 27 November 2023. https://verra.org/wp-content/uploads/2023/11/VMD0001-Estimation-of-Carbon-Stocks-in-Above-and-Belowground-Biomass-in-Live-Tree-and-Non-tree-Pools-CP-AB-v1.2.pdf

3 Verra (2020): VCS Module VMD0007. Estimation of baseline carbon stock changes and greenhouse gas emissions from unplanned deforestation and unplanned wetland degradation (BL-UP). Version 3.3, 8 September 2020. https://verra.org/wp-content/uploads/imported/methodologies/VMD0007-BL-UP_v3.3.pdf

4 Verra (2020): VCS Module VMD0009. Estimation of emissions from activity shifting for avoiding planned deforestation/forest degradation and avoiding planned wetland degradation (LK-ASP). https://verra.org/wp-content/uploads/imported/methodologies/VMD0009-LK-ASP-v1.3.pdf

5 Verra (2020): VCS Module VMD0010. Estimation of emissions from activity shifting for avoiding unplanned deforestation and avoiding unplanned wetland degradation (LK-ASU). https://verra.org/wp-content/uploads/imported/methodologies/VMD0010-LK-ASU-v1.2.pdf

6 Verra (2023): VCS Module VMD0011. Estimation of emissions from market-effects (LK-ME). Version 1.2, 27 November 2023. https://verra.org/wp-content/uploads/2023/11/VMD0011-Estimation-of-Emissions-from-Market-effects-LK-ME-v1.2.pdf

7 Verra (2010): VCS Module VMD0012. REDD Methodological Module: Estimation of emissions from displacement of fuelwood extraction (LK-DFW). Version 1.0, 3 December 2010. https://verra.org/wp-content/uploads/imported/methodologies/VMD0012-LK-DFW-v1.0.pdf

8 Verra (2020): VCS Module VMD0015 Methods for monitoring of GHG emissions and removals in REDD and CIW projects (M-REDD). Version 2.2, 8 September 2020. https://verra.org/wp-content/uploads/2023/11/VMD0015-M-REDD-v2.2.pdf

9 Verra (2020): VCS Module VMD0017. Estimation of Uncertainty for REDD+ Project Activities (X-UNC), Version 2.2, 8 September 2020. https://verra.org/wp-content/uploads/imported/methodologies/VMD0017-X-UNC_v2.2.pdf

10 CDM-Executive Board (2007): A/R Methodological tool. Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities, Version 01. https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-02-v1.pdf

11 Verra (2022): VCS Standard. Version 4.2, 20 January March 2022. https://verra.org/wp-content/uploads/2022/02/VCS-Standard_v4.2.pdf

12 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 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.
- **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.

The CCQI project types, as described above, are applicable to the methodology. The methodology also applies to activities for avoiding unplanned forest degradation caused by fuelwood extraction from forests. Moreover, the methodology also includes activities such as wetland restoration and conservation, afforestation, reforestation, and revegetation. The methodology also explicitly applies to mangrove ecosystems.

OE1 **Lack of clarity of the methodology:** VM0007 is mostly a compilation of a large number of modules and tools that together define the methodology. Some of the 37 modules and tools referred to are mandatory and some are not. However, the large number of modules and tools are not properly linked and not properly referenced. The referenced tools and modules include further references to other modules. For example, module VMD0015 refers to 14 other modules. It is often not clear how these modules should be combined to quantify emission reductions, and which approaches from the respective modules should be used. Monitoring reports from projects registered under VM0007 also report on contradictions between different modules and tools that are essential parts of the methodology. Some modules or tools can also not be found through the search function of the VCS methodology webpage. This approach is not user-friendly and results in a rather incomprehensible methodology. This makes it prone to errors, misunderstandings, and mistakes and provides possibilities for overestimation or underestimation of emission reductions and introduces uncertainty in the quantification of emission reductions. 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 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. If logging (either legal or illegal) 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. For these reasons, through our analysis we assume that 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 for both planned and unplanned deforestation.

VM0007 provides generic guidance regarding the inclusion of carbon pools: “Any significant decreases in carbon stock in the project scenario and any significant increases in carbon stock in the baseline scenario must be accounted for. In addition, decreases in the baseline scenario and increases in the project scenario can be accounted for.” The methodology also requires that carbon pools “included in the baseline accounting … must also be included in project scenario and leakage accounting.”

For two carbon pools, the methodology identifies conditions under which the pools must be included: “Harvested wood products and deadwood must be included when they increase more or decrease less in the baseline than in the project scenario.” However, the methodology does not contain a provision requiring that specific modules be used to calculate HWP and deadwood to determine whether the conditions apply under which the inclusion of these pools is mandatory.

The methodology requires that aboveground biomass be included but does not specify whether this applies to both tree and non-tree biomass.

Other carbon pools are not properly defined in the methodology and their inclusion or exclusion is therefore left up to the project proponents that need to identify all relevant pools. For avoided deforestation, the methodology refers to Table 4 which presents the modules for quantification of various carbon pools and emission sources; however, neither this table, nor the relevant modules identify the carbon pools. Carbon pools are specified for afforestation reforestation and regeneration (ARR) and wetland restoration and conservation (WRC) activities that may be part of avoided deforestation projects, but as this is not applicable to land areas where deforestation is avoided, they are here not assessed. Carbon pools that must be considered for ARR and WRC activities are illustrated in Table 1. Table 1 shows many carbon pools as excluded when quantifying the WRC activities of an avoided deforestation project because they are identified as being “covered under REDD”. This “covered under REDD” designation is interpreted to mean that these carbon pools must be included by avoided deforestation activities under VM0007 but no provisions identifying that these pools must be included in avoided deforestation activities were identified.

Table 1 Assessment of sources, sinks, reservoirs

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Carbon Pools		
Aboveground tree biomass	excluded	Covered under REDD or ARR
Aboveground non-tree biomass	excluded	Covered under REDD or ARR
Herbaceous biomass	excluded	Covered under ARR
Belowground biomass	included	This pool is not distinguished from the soil pool in wetland restoration and conservation procedures. It remains unclear where mosses characterizing peat are accounted as they are not soil organic carbon
Dead wood	excluded	Covered under REDD or ARR
Litter	excluded	Covered under REDD or ARR
Soil organic carbon (SOC)	included	Procedures in Modules BL-PEAT, M-PEAT, BL-TW and MTW account for emissions from the soil pool based on proxies and default factors
Harvested Wood Products	excluded	Covered under REDD or ARR

The methodology also identifies the emission sources that should be included or excluded for avoided deforestation projects. Table 2 below presents the pools and sources that are relevant to the VM0007 and information regarding their inclusion/exclusion.

Table 2 Assessment of sources, sinks, reservoirs

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Carbon pools		
Aboveground tree biomass	Assumed to be included for baseline and project but the methodology lacks clarity	Major carbon pool affected by projects.
Aboveground non-tree biomass	Unclear	In the baseline scenario (post-deforestation land-use for agriculture), non-tree biomass such as shrubs are likely to be removed. Therefore, inclusion of this pool in the baseline and project scenarios would likely increase the project's quantified impact and exclusion would be conservative.
Belowground tree biomass	Not-specified – general guidance applies: "Any significant decreases in carbon stock in the project scenario and any significant increases in carbon stock in the baseline scenario must be accounted for. In addition, decreases in the baseline scenario and increases in the project scenario can be accounted for."	Major carbon pool affected by projects. Exclusion of this pool in the baseline and project scenario would likely be conservative.
Belowground non-tree biomass	Not-specified – general guidance applies.	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	Conditionally included when pool increases more or decreases less in the baseline than in the project scenario, i.e., leading to greater quantified project impact, otherwise optional to include.	In the baseline scenario, slash deadwood would result from harvesting (which does not occur in the project) but when the land use shifts to agriculture, deadwood would be burned or removed. 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	Not-specified – general guidance applies.	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)	Required when project activities take place in wetlands, otherwise 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.
Harvested Wood Products (HWP)	Conditionally included when pool increases more or decreases less in the baseline than in the project scenario, i.e., leading to greater calculated emission reductions, otherwise optional to include.	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 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 whether the stock change is higher in the baseline than in the project. This seems appropriate.

Emission sources		
Emissions from biomass burning	CO_2 included in the project scenario, but optional in the baseline scenario. The module VMD0013 (which is referenced in the methodology used to calculate emissions from biomass burning) states that inclusion of fire in the baseline "is always optional".	Could be an important emission source in the baseline and project scenario. Proponents must include these emissions in the project scenario. If project proponents opt not to include the emission source in the baseline (as indicated by VMD0013) this would be conservative.
	CH_4 and N_2O lack clarity. The sources are identified as included, but the explanation states that "it is conservative to exclude" for the baseline scenario. These sources must be included in the project accounting if fire occurs.	Conservative to exclude in the baseline scenario, but major emissions source in project scenario.
Combustion of fossil fuels	CO_2 lacks clarity. The source is identified as included, but the explanation states that "it is conservative to exclude" for the baseline scenario. Clarity is also lacking in the project scenario where it states that CO_2 is included, but that it "can be neglected if excluded from baseline accounting". The lack of clarity leaves room for this source to be excluded.	Exclusion may lead to uncertainty because emissions from combustion may increase or decrease as a result of project activities relative to baseline. Under the baseline scenario, emissions from combustion of fuel in harvesting equipment and fuel in crop production equipment occurs. In the project scenario emissions may increase from equipment used in monitoring or patrolling the project area.
	CH_4 and N_2O are excluded, as they are considered negligible.	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.
N_2O emissions from application of fertilizer	Lacks clarity. The source is identified as included, but the explanation states that "it is conservative to exclude" for the baseline scenario. The source is included in the project, but can be excluded if excluded from the baseline, unless fertilizer use increases due to the project.	In the baseline scenario, fertilizer use may increase or decrease over time. Where fertilizer use in the baseline is excluded, this is conservative. Exclusion in the project where fertilizer does not increase compared to the baseline is appropriate and conservative.
Livestock emissions	Excluded (not addressed)	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.

OE2 **Lack of clarity regarding which emissions sources and carbon pools must be considered:** For many carbon pools and emission sources, the methodology is not clear whether and under which conditions they must be included or may be excluded, providing flexibility to project developers on whether to include or exclude these carbon pools and emission

sources. Project developers have an incentive to favorably interpret the methodology and pick and choose which carbon pools and emission sources they include or exclude, depending on the project circumstances. This may lead to overestimation of emission reductions. This issue is likely to apply to a **high** fraction of projects. The impact on total credited removals or emission reductions is estimated to be **low to medium** (0-30%). The variability in the degree of overestimation among projects is estimated to be **high**.

VM0007 explains that insignificant emission sources may always be excluded and that "T-SIG or Appendix 1 may be used to determine whether an emissions source is significant." Elsewhere in the methodology section 8.3 on leakage it states, "The significance of leakage and the significance of carbon pools must be determined using T-SIG or Appendix 1" but this neglects to require significance testing for emission sources and conflicts with other methodological provisions. T-SIG is the CDM Tool for testing the significance of a source or pool. This tool is no longer valid under the CDM, which makes it unclear whether it can actually be used. Moreover, in contrast to other avoided deforestation methodologies, there are contradictory provisions within the methodology regarding whether there exists a requirement to use either of the two tools for leakage sources and carbon pools, and no requirement to test the significance of emission sources.

OE3 **The determination of significance of carbon pools and leakage sources is unclear and is not required for emission sources**: In the absence of a consistent provisions that require proponents to determine the significance of each source and pool (i.e., because the methodology says that "T-SIG or Appendix 1 may be used to determine whether an emissions source is significant" instead of must or shall be used), project proponents may exclude sources that would be determined to be significant, if T-SIG or Appendix 1 were applied. This may lead to overestimation of emission reductions. The number of projects affected is **unknown**. The impact on total credited removals or emission reductions is **unknown**. The variability in the degree of overestimation among projects is estimated to be **unknown**.

OE4 **Factors determined to be insignificant can be excluded without any limitations and project developers may choose from two methods to determine significance**: The approach provides leeway to project developers regarding how significance is assessed. Project developer could pick from two methods to assess the significance for each source in such a way that more significant project or leakage sources are excluded (using a method that tends to underestimate them) and conversely minor sources are included (using a method that tends to overestimate them). Additionally, unlike other avoided deforestation methodologies, there is no overall threshold limiting the amount of total emissions that may be deemed insignificant and excluded from the project (e.g., this threshold is no more than 5% of total project emissions in VM0006). This may lead to overestimation of emission reductions. The number of projects affected is **unknown**. The impact on total credited emission reductions is estimated to be **low to medium** (up to 30%). The variability in the degree of overestimation among projects is estimated to be **high**.

UE1 **Inclusion of aboveground non-tree biomass is optional:** The methodology is not clear whether aboveground non-tree biomass must be included in the project boundary. We interpret the different provisions to mean that inclusion 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 **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**.

UE3 **Deadwood is an optional source**. 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. 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** (except when project activities are implemented in wetlands)**:** 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**.

UE6 **Emissions from biomass burning are identified as an optional source in the baseline:** Emissions of CO_2 from biomass burning are identified in VMD0013 as "always optional" despite it being "included" in the VM0007 methodology. If these emissions occur in the baseline scenario, their exclusion lowers the baseline emissions, and therefore leads to underestimation. This issue applies to projects that opt to exclude CH_4, N_2O, and potentially CO_2 emissions from biomass burning. 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 does not consider CH_4 emissions from livestock:** Livestock emissions within project boundaries are likely to decrease compared to a baseline scenario where deforestation occurs to allow livestock production. Excluding livestock emissions from baseline and project is therefore likely to result in underestimation. 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**.

UE8 **N_2O emissions from the application of fertilizer are optional unless fertilizer use increases due to the project:** The use of fertilizer in the baseline and project scenario is highly dependent on local conditions and common fertilizer use. If fertilizer use increases due to the project as a result of the implementation of leakage prevention measures, it must be included and accounted for. 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 emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

Un1 **Inclusion of CO_2 from the combustion of fossil fuels is unclear but interpreted to not be required**: 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 removals or 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

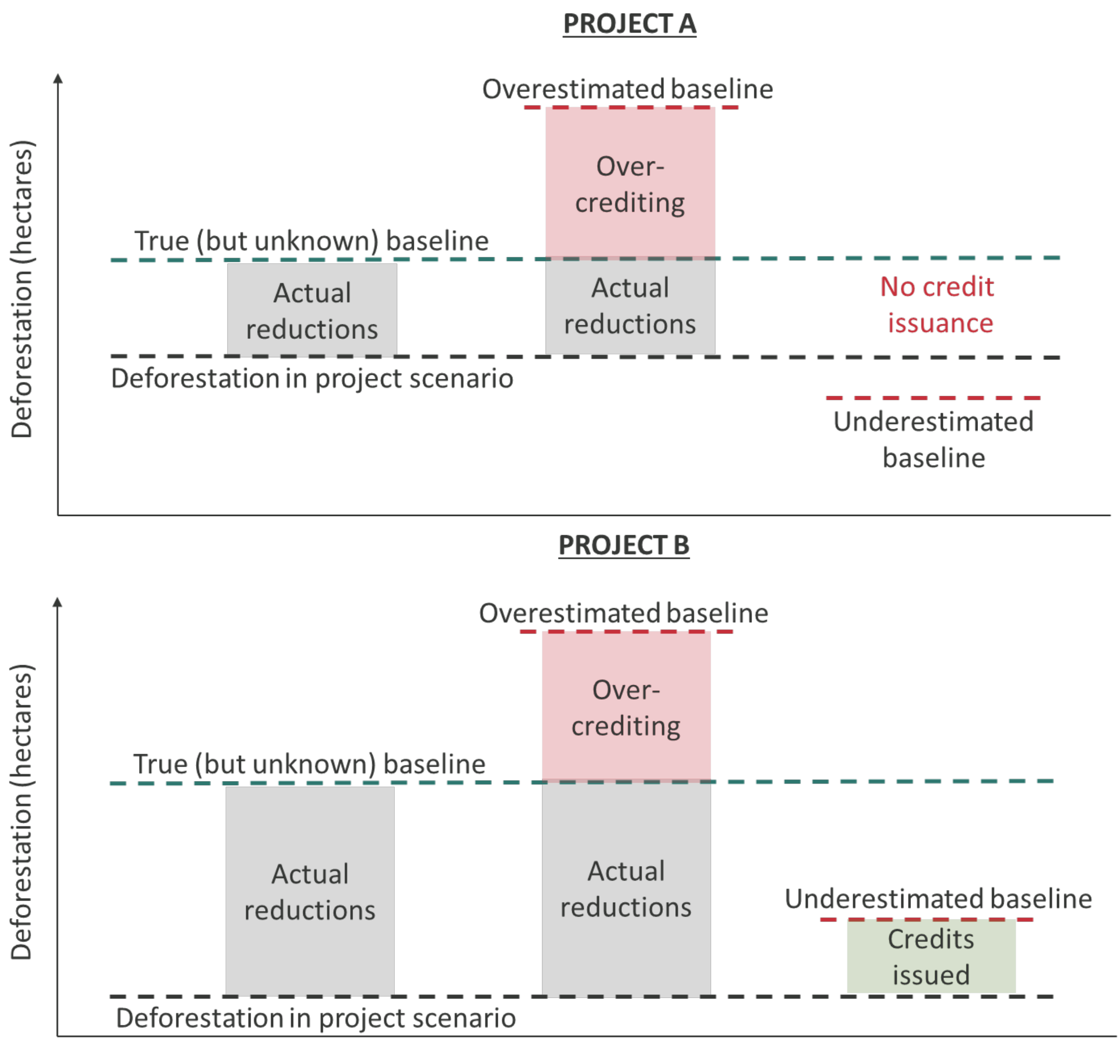
Establishing baselines for avoided deforestation projects is associated with very large uncertainty. Establishing baseline is always associated with uncertainty, as it is not directly observable what would have happened in the absence of a project. For avoided deforestation projects, uncertainty in establishing 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:

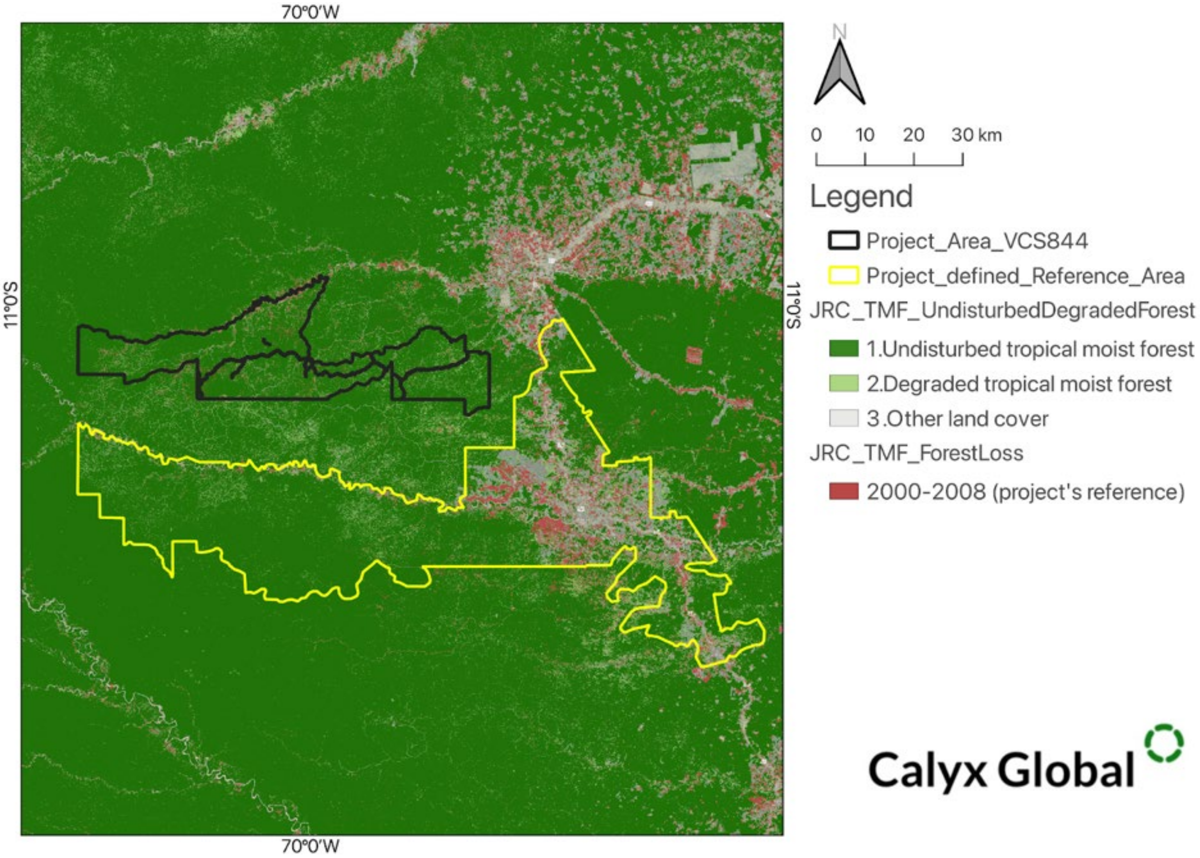
- **Choice of the reference area or region:** The historical deforestation in a reference region is used to estimate the baseline deforestation rates. Although the methodologies provide criteria for ensuring that reference areas match the characteristics of the project area, these do not necessarily 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 VM0007

Methodology VM0007 is composed of several modules. VMD0007 is used for determining baselines for projects avoiding unplanned deforestation. VMD0006 is used for determining baselines for projects avoiding planned deforestation.

The methodology requires defining project-type specific spatial boundaries. For avoided unplanned deforestation projects, proponents must define the project area, a reference region, and a leakage belt area. Together these areas are referred to as the “analytical domain”. The project area must exclude areas of planned deforestation. For avoided planned deforestation projects, proponents must define the project area and if needed proxy areas.

One project may be composed of multiple discrete and non-overlapping project areas. These are fixed prior to the project start and cannot be changed. Each project area may belong to a different project type and must consequently have its own baseline. For example, a project may have one project area where the project type is avoided unplanned deforestation and another project area where the project type is avoided planned deforestation. The baseline for each project area must be defined using the respective module. For simplicity, this analysis will refer to project areas.

The historical reference period must start between 9 and 12 years prior to the project start date and end within two years prior to the project start date. As such its duration may range between 7 and 12 years. The project area must have been forested at least ten years prior to the project start date and be covered by 100% forest at the project start date.

Avoided unplanned deforestation

The baseline scenario is determined by the steps specified in the Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities, referred to by the methodology as “T-ADD” (identification of alternative land use scenarios, investment analysis, barrier analysis, common practice analysis). The baseline validity period was originally ten years and is six years since version 4.2. of the methodology. For each subsequent baseline validity period the baseline must be reassessed. The methodology states that the starting point for the baseline revision “will be the forest cover projected to exist at the end of the baseline period”.

The main steps for constructing the baseline are the definition of spatial and temporal boundaries, the estimation of annual areas of unplanned deforestation from historical remote sensing imagery in a reference region, the analysis of the location of future deforestation (e.g. through a deforestation risk map), and the calculation of carbon stock changes and GHG emissions.

Two alternative approaches for constructing the baseline are provided:

1. Historic approach: Baselines based on observed historical deforestation trends in the reference region. If this approach is chosen additional options for projecting future baseline deforestation can be used:
    a. The historical average annual deforestation during the historical reference period;
    b. Extrapolation of past deforestation trends based on a linear regression;
    c. Extrapolation of past deforestation trends based on a non-linear regression (exponential or logarithmic).

2. Population driver approach: Baselines based on the observed historical relationship between population and deforestation in the reference region and a function of population increase in the reference region. This approach may only be used if two or more population census data points are available from within 20 years prior to the project start date and if periodic population census updates (at least every 10 years) are expected. Also, the common practice must be that non-forest land in the reference region "is not left idle for more than 10 years", to ensure that a growing population does not meet its requirements from existing non-forest land.

The methodology indicates that two types of reference regions must be selected. The first reference region is selected for determining the baseline deforestation rate. It must be 100% forested at the start of the historical reference period, must not include the forest area or leakage belt and does not have to be contiguous to the project area. The second reference region is selected for assessing the location of future deforestation. It must contain the project area and leakage belt, be at least 50% forested at the project start date and have a proportion of forest land that is comparable to the first reference region, within ± 25%. The two reference regions may overlap or be distinct. If they overlap, the methodology does not specify whether this is a total or a partial overlap. A deforestation risk map used in the population driver approach is developed using the second reference region.

If the historic approach to setting the baseline is used, the analysis of historical deforestation is done by first analyzing land cover from historical maps within the historical reference period. At least three different images, three or more years apart must be used. The spatial resolution must be 30m x 30m or less. Any source of remotely sensed data and analysis method can be used. Additional requirements to improve accuracy are included for the oldest image. Next, historical deforestation is estimated by defining polygons and classifying them into forest land, non-forest land and deforested land. Deforested land is identified through the comparison of two consecutive maps. The minimum accuracy of forest and non-forest classification must be 90% otherwise maps are not accepted, and additional data sources and analyses are required to improve accuracy. This analysis delivers the total area of forest at the beginning and at the end of the historical reference period, as well as the number of hectares deforested land between time points (i.e. gross deforestation between the beginning and the middle of the reference period and between the middle and the end). Based on this information the next step is to calculate the area of unplanned baseline deforestation using one of the options mentioned above. A regression can only be used if it is found to be significant ($p \leq 0.05$), to have $r^2 \geq 0.75$ and is free from bias. The non-linear regression can only be used if at least five points in time in the historical reference period have been analyzed. If the linear regression shows a decreasing trend, then this trend must be used. If a historical average is used, the project proponent must demonstrate that deforestation is unlikely to decrease in the baseline. Finally, the annual area of unplanned baseline deforestation in the project area is calculated using the ratio of forest area in the second reference region.

If the population driver is used, baseline deforestation is determined by first analyzing historical deforestation and its correlation to population. Project proponents must determine a parameter that expresses the change in deforested area (ha) resulting from a change in population (number of individuals), referred to as DP = "Forest area that is cleared per additional person(s) entering the population". DP can be estimated through a survey approach or modelling using analysis of historical imagery and census data. To improve accuracy, the reference region may be subdivided according to socio-economic factors and land use practices. Each subdivision may then be assigned its own DP value. The next step is to calculate a population growth rate. The annual area of unplanned deforestation in the reference region is calculated by multiplying the difference in population in two time points with DP. This is followed by the preparation of a deforestation risk map to assess the location of future deforestation. If no risk map and location analysis of future deforestation is carried out, deforestation is assumed to occur first in the strata with the lowest carbon stocks (this is referred to as the conservative approach). Finally, the annual area of unplanned baseline deforestation in the project area in the project area is calculated, assuming that the pixels with the highest deforestation risk are deforested first.

Avoided planned deforestation

Baseline emissions are calculated by determining the expected annual area of deforestation and multiplying it by the expected net carbon stock change (pre-deforestation carbon stock minus post-deforestation carbon stock minus baseline stock that enters the harvested wood product pool) and by adding GHG emissions from fossil fuel combustion, biomass burning and N_2O emissions from nitrogen application in the alternative land use.

Determining the annual area of deforestation requires the following steps:

- Identification of agents of deforestation: The agents may already be known (simple scenario) or the deforestation agent may not yet known. In the latter case the most likely deforestation agent must be identified. Deforestation agents may be individuals, organizations, companies and associations. These include agri- and aquabusinesses and ethnic or religious groups. A difference is made between industrial scale agri- and aquaculture (nor further definitions provided), and large scale agri- and aquaculture practiced on parcels larger than 500 ha. Project proponents are also required to identify whether the agents of deforestation implement specific land use regulations. Project proponents must substantiate the selection of the deforestation agent using stratification and historical records. Stratification must be based on forest carbon stocks, "biophysical parameters related to forest productivity" (e.g. soil type, slope, precipitation, temperature, elevation), and parameters that influence the conversion activity (e.g. distance to roads and rivers, distance to forest edge, distance to settlements).

- Defining the area of planned deforestation: This requires demonstrating the existence of an "immediate site-specific threat of deforestation". This is done by providing documentation proving that deforestation is legal with regards to laws and legal requirements and considering already deforested areas within the total property of the deforestation agent as well as suitability of the forest land for the alternative land use (e.g. because of biophysical conditions and access to markets). In some cases, where the deforestation agent does not own the land or the rights to deforest it, proof must be provided that the transfer of ownership would have occurred in the absence of the project. In jurisdictions where government approval is required, documentation proving that planned deforestation has been approved or the request for approval must be provided. Finally, the intention of the baseline deforestation agent to carry out the planned deforestation must be provided.

- Determining the expected deforestation rate (ha/year for each stratum): The rate must be defined from a "valid verifiable plan" from the deforestation agent if it exists. If no such plan exists, the rate is defined by analyzing information from at least six poxy areas. The methodology provides criteria for defining the proxy areas, e.g. similarity in conversion practices, the same post-deforestation land use, same management and land use rights, vicinity to the project area, deforestation of the proxy area must have occurred within 10 years prior to the baseline period, and similarity in the forest type, soil type and elevation (±20% in all three variables). Deforestation rates in the proxy areas may be determined through field measurements and/or remote sensing analysis or by using already existing and credible data.

- Defining the likelihood of deforestation: To determine this likelihood the methodology distinguishes between areas that are under government control and zoned for deforestation, and areas that are not under government control. For areas under government control, a representative sample of proxy areas must be taken, and the likelihood of deforestation will be equal to the proportion of similar zones that have been deforested in the past five years. For areas not under government control, e.g. already under control of the deforestation agent, deforestation likelihood is assumed to be 100%. This module cannot be used if there is a risk of abandonment. A risk of abandonment exists if an analysis of at least five proxy areas deforested within the ten years prior to the start date shows that any of them have been abandoned.

We identify the following issues related to baseline setting for avoided unplanned deforestation projects:

OE5 **Flexibility in choosing the approach for estimating the baseline for avoiding unplanned deforestation:** Project proponents have the option to choose from several alternatives for constructing their baseline. Although the availability of remote sensing imagery or population data is a constraining factor, project proponents may still have considerable leeway in selecting between different approaches and can thus choose an approach that results in higher baseline deforestation rates. Different approaches to setting baselines result in very different estimates of future deforestation (Haya et al. 2023, West et al. 2023, Guizar-Coutiño et al. 2022) and the methodology does not require that project proponents demonstrate the conservativeness of their choice. This flexibility may lead to an overestimation of credited emission reductions. The fraction of projects affected is estimated to be **high**. The impact on total credited emission reductions is **unknown**. It is likely to be higher for baselines constructed with the population driver approach and a non-linear regression than for, the other baseline types. The variability among in the degree of overestimation among projects is also **unknown**.

OE6 **Flexibility in the selection of the reference region for unplanned deforestation projects for baselines using historic deforestation rates***:* The methodology provides the following flexibilities when determining the reference region:

- Size of the reference region: A formula for calculating the minimum size of the reference region is provided. It is calculated as a function of the project area using a reference area factor. Smaller project areas require a larger reference region. Starting from a project area of around 340,000 ha, the minimum size of the reference region corresponds to the project area (see equations 1 and 2 in VMD0007). The methodology does not specify if the area resulting from the calculation must be used, it is thus possible, that project proponents can also choose a larger reference region, if convenient.

- Shape and boundary of the reference region: Criteria for selecting the boundary of the reference region relate to the agents of deforestation, landscape factors (forest classes, soil types, slope, elevation classes), settlements, transportation networks (rivers and roads), social factors, polices and regulations. For each of the criteria there are either options how similarity can be determined or there is a range for the similarity (±20%). For example, in the case of road density (m/km^2) this must be "the same, less than or does not exceed by more than 20% that of the project area". The allowed deviation permits project developers to potentially select a reference region with higher road density, and since roads are a main factor in deforestation, this choice may lead to higher baselines.

- Reference regions may not be representative of the project area: If a not sufficiently large reference region that matches the selection criteria can be found, the methodology provides several steps on how to adjust the selection. First, the size of the reference region may be reduced to the area that fits all criteria. Second, if the resulting area is half of the minimum size, then the threshold for selection criteria is lowered to +/-30%. Third, if still no area that is at least half of the minimum size can be found, criteria related to policies and regulations can be relaxed, but still aiming to select a region where policies and regulations have a comparable effect on land use change. If the third option is applied, the deforestation rate in the baseline cannot have an increasing trend. These provisions provide further leeway to project developers to select a favorable reference region.

Overall, the provisions in the methodology 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 fraction of projects affected by this issue is estimated to be **high**, given the strong economic incentives for project developers to choose a favourable project area and given the available evidence with the selection of reference areas (see, for example, Calyx Global 2023; Haya et al. 2023). 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 also estimated to be **high**, given the large variations in the degree of overestimation report (see, for example, Calyx Global 2023).

OE7 **Flexibility in the selection of the reference region for unplanned deforestation projects for baselines using the population driver approach:** The area of the reference region is defined by the area of “population census units”. These must include and surround the project area, as well as all significant forest areas surrounding the project. Significant forest areas are those that are “accessible and attractive to local deforestation agents”. The following flexibilities are provided for choosing the reference region:

- Significant forest areas that are attractive and accessible to deforestation agents must not necessarily be adjacent to the project area. This provides flexibility for selecting forest areas with high deforestation risk.
- The project area is expected to be located “roughly in the middle of the reference region” to avoid bias from forest edge, but no further requirements are provided, and project proponents may make discretionary choices and justify them accordingly. Due to information asymmetry, verification and validation bodies may not be able to correctly identify bias.
- Exceptions to the selection criteria are possible so that specific population census units can be excluded. Exceptions relate to the mobility of deforestation agents and regulatory circumstances but also to “other appropriate regional and socioeconomic factors”. The criteria can be assessed using qualitative assessments, opinion of local expert or literature sources. Any exclusion of census units with low population densities

would create a bias in the reference region but is possible because any appropriate reason for exclusion may be provided.

The provided flexibility creates the risk that project developers select a reference region with higher population pressure than is likely to occur in the project. The number of projects affected by this issue is estimated to be **high** given the strong economic incentives for project developers to choose a favourable project area. 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 also estimated to be **high**, given the large variations in the degree of overestimation report (see, for example, Calyx Global 2023).

Un2 **Flexibility in choosing the modelling approach for deforestation risk mapping:** The methodology specifies the conditions for when a risk map can or must be used. If the population driver approach for baseline setting is used, the use of a risk map is mandatory, regardless of the landscape configuration. If the landscape configuration is frontier forest, the use of a risk map is also mandatory, regardless of the baseline approach. If the landscape configuration is mosaic, or a transition ("≥25% of the project geographic boundary is within 50 m of land that has been anthropogenically deforested within the 10 years prior to the project start date") and the historic approach to baseline setting is used, project proponents may choose to use a risk map. Any approach for constructing the risk map can be used, if it is peer reviewed and transparent. 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 most accurate risk map must be selected (e.g. best fit or highest figure of merit). No guidance is provided for how many risk classes should be used. The methodology does not require that different risk mapping models be compared. It requires a comparison of different outcomes from one model, but not a comparison among 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". The methodology includes an alternative approach, explicitly referred to as a "conservative approach", for when no assessment of the location of future deforestation is done. In that case it is assumed that deforestation first occurs in the strata with the lowest carbon stocks. This issue is likely to apply a **high** fraction of projects. For those projects where this issue materializes, the impact on total credited emission reductions is **unknown**. The variability in the degree of overestimation among those projects for which the issue materializes is **unknown**.

Un3 **Uncertainty in the models used to establish the risk map:** Allocating the deforestation risk in risk maps is associated with considerable uncertainty. The goodness of fit (accuracy) of the models used strongly hinges on how well different effects and drivers for deforestation can be reflected in the model. The methodology does not account for the model uncertainty in preparing the risk map. The methodology does not pursue a conservative approach to address uncertainty (e.g. by making a deduction to account for model uncertainty). This issue applies to **all** projects. The degree of uncertainty and the variability among projects is **unknown**.

We identify the following two issues specific to the population driver approach:

Un4 **Uncertainty in determining the DP:** The methodology provides two options for determining the population parameter and provides requirements for how it should be developed. The following issues contribute to uncertainty in establishing the parameter:

- Choice of method: DP can be estimated through survey methods, or a regression based on the analysis of historical imagery and census data. Survey methods include participatory appraisals. The survey is used to determine parameters at the household level for the last ten years related to the area of unplanned deforestation per household, the number of people immigrating to the reference region and children born. Alternatively, historic imagery and population census data from within 20 years before the project start date can be used to construct a regression model from which to determine the parameter.

- Use of interpolation and extrapolation for constructing the regression model: The methodology provides options to determine DP even if appropriate population data and imagery for the same year cannot be found. In this case, data can be interpolated between events or extrapolated from the latest census. If no official population data is available, other sources may be used.

- Alternative approach for constructing the regression model: An alternative approach for developing the regression model is provided to address lack of data. If data for multiple years is available, the so-called dynamic approach is used, where the independent variable is change in population and the dependent variable is change in area of unplanned deforestation. The model must be "statistically significant ($p < 0.05$), and unbiased (i.e., minimal trend in residuals), with an adjusted $r^2 \geq 0.50$)". In the alternative approach (static approach), where data for several census units is available for only one year with a coinciding spatial imagery, a linear regression is used where population is the independent variable, and the area of unplanned deforestation is the dependent variable. The same quality criteria as for the dynamic approach apply. The static approach can only be used for the first baseline and if the regression under the dynamic approach does not meet the quality criteria. If the regression under the static approach is not significant, DP is 0.

- No uncertainty assessment: The methodology states that "it must further be demonstrated that the resulting DP parameter does not represent a spurious correlation between population and deforestation, substantiated through a qualitative assessment, opinion of local experts or literature sources." However, no uncertainty analysis for DP is required.

The issue applies to **all** project using the population driver approach. The issue introduces a **high** degree of uncertainty to the estimation of total credited emission reductions. The variability among those projects for which the issue materializes is **unknown**.

OE8 **Use of an exponential population growth rate:** If only two data points are available, a linear regression must be used for determining the population growth rate (constant growth rate). If three or more population census dates are available, and it can be demonstrated that population increased in at least two intervals, then an exponential model can be used for predicting future population growth. No uncertainty assessment is required or ex-post verification to test whether the assumption of exponential population growth is true. Also, no limiting factors for population growth are considered. Since population growth is the driver of deforestation an overestimation of the population growth rate would also result in an overestimation of the deforestation rate and therefore credited emission reductions. The issue applies to **all** project that apply the exponential model to determine the population growth rate. The impact on total credited emission reductions is estimated to be **high** (larger than 30%). The variability among those projects for which the issue materializes is **unknown**.

We identify the following issues with baseline setting for avoided planned deforestation projects:

Un5 **Flexibility in choosing the proxy area:** The methodology provides several criteria for selecting proxy areas and for ensuring similarity between the proxy area and the project area. However, it allows for deviations with relation to the proportion of forest types present in the proxy area and the project area, soil type, slope and elevation classes (±20%). Most importantly, it states that “if no proxy area exists under the same land use management/rights type” then other representative lands under different land use right types may be used as the proxy area. This flexibility creates the risk that project developers select proxy areas with higher planned deforestation than is likely to occur in the project area. The number of projects affected by this issue is **unknown** but could likely be high because project proponents have an implicit incentive to choose proxy areas that indicate higher levels of planned 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**.

Un6 **Uncertainty in determining post deforestation carbon stocks:** Post-deforestation carbon stocks can be measured in the proxy area or selected from credible and representative literature sources. The methodology does not require an uncertainty analysis of estimated carbon stocks and does not provide any requirements for using recent and conservative data. This issue applies to **all** projects. The level of uncertainty and variability among projects are **unknown**.

OE9 **Overestimation due to changes in intent of deforestation:** When it comes to defining the area of planned deforestation, the methodology requires that for all projects there must be an “immediate site-specific threat of deforestation. The threat must be concrete and would lead to deforestation within a defined period of time.” Also, proof of intent of deforestation by the baseline agent must be provided. This includes a “valid and verifiable land use management plan, or a documented history of similar planned deforestation activity by the baseline agent within the five years prior to the without-project deforestation.” If government approval is required before deforestation, “recent approval” from relevant government agencies for forest conversion is required or documentation that a request for approval has been filed. It is not further defined what recent means or when a request for approval must have been filed, for example how it relates to the project start date. Assuming all criteria must be valid within five years of the project start date, this is a sufficiently long period in which the intent of deforestation may change, for example due to changes in commodity prices and markets, changes that impact the operating capacity of the deforestation agent and changes in regulations or requirements. Due to information asymmetry, it is not possible to know the true intent of deforestation. If the threat and intent of deforestation are overestimated, this would lead to an overestimation of the area of planned deforestation and the credited 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 **high** (larger than 30%). The variability among those projects for which the issue materializes is **unknown**.

OE10 **Assumption of a likelihood of deforestation of 100%:** The annual area of planned deforestation is specified in equation 5. The total area of planned deforestation is multiplied by a factor representing the annual proportion of a stratum deforested per year and the likelihood of deforestation. The likelihood of deforestation is determined differently depending on whether the project area is under government control and zoned for deforestation or is under control of the deforestation agent. When areas are under government control, the likelihood of deforestation is determined by looking at the deforestation in proxy areas in the previous five years. Otherwise, the likelihood is set to 100%. This simplified assumption could lead to an overestimation of emission reductions, because multiple factors may affect whether a deforestation agent actually carries out its planned deforestation. The number of projects affected by this issue is **unknown**. 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**.

Un7 **Limited guidance for analyzing deforestation rates in the proxy area**: The proxy area is used to estimate "the average proportion of land that is cleared each year". An unspecified number of parcels must be analyzed to be representative of the common practice in the proxy area. Data can be generated through field measurements and/or analysis of remote sensing imagery, but "directly applicable existing data generated from credible sources" can also be used. No further guidance is provided, for example related to sampling approaches, spatial resolution of remote sensing imagery, or quality criteria for existing data are provided. No uncertainty analysis or requirement to use conservative numbers are included. Hence deforestation levels in the project area could be over- or underestimated. The issue applies to **all** projects. This issue is estimated to introduce 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**.

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:

OE11 **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. For example, a 10% canopy cover is 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. 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**.

Un8 **Overall uncertainty assessment:** The methodology requires projects to use module VMD0017 to combine uncertainty information and conservative estimates and produce an overall uncertainty estimate of the total net emission reductions. This is a useful feature, but the module does not refer to good practice methods such as using error propagation methods for this purpose. The methodology and the module also do not specify the general level of accuracy that has to be achieved for the monitoring of the overall project emissions and removals. This affects **all** projects. The level of uncertainty and the variability among projects are **unknown**.

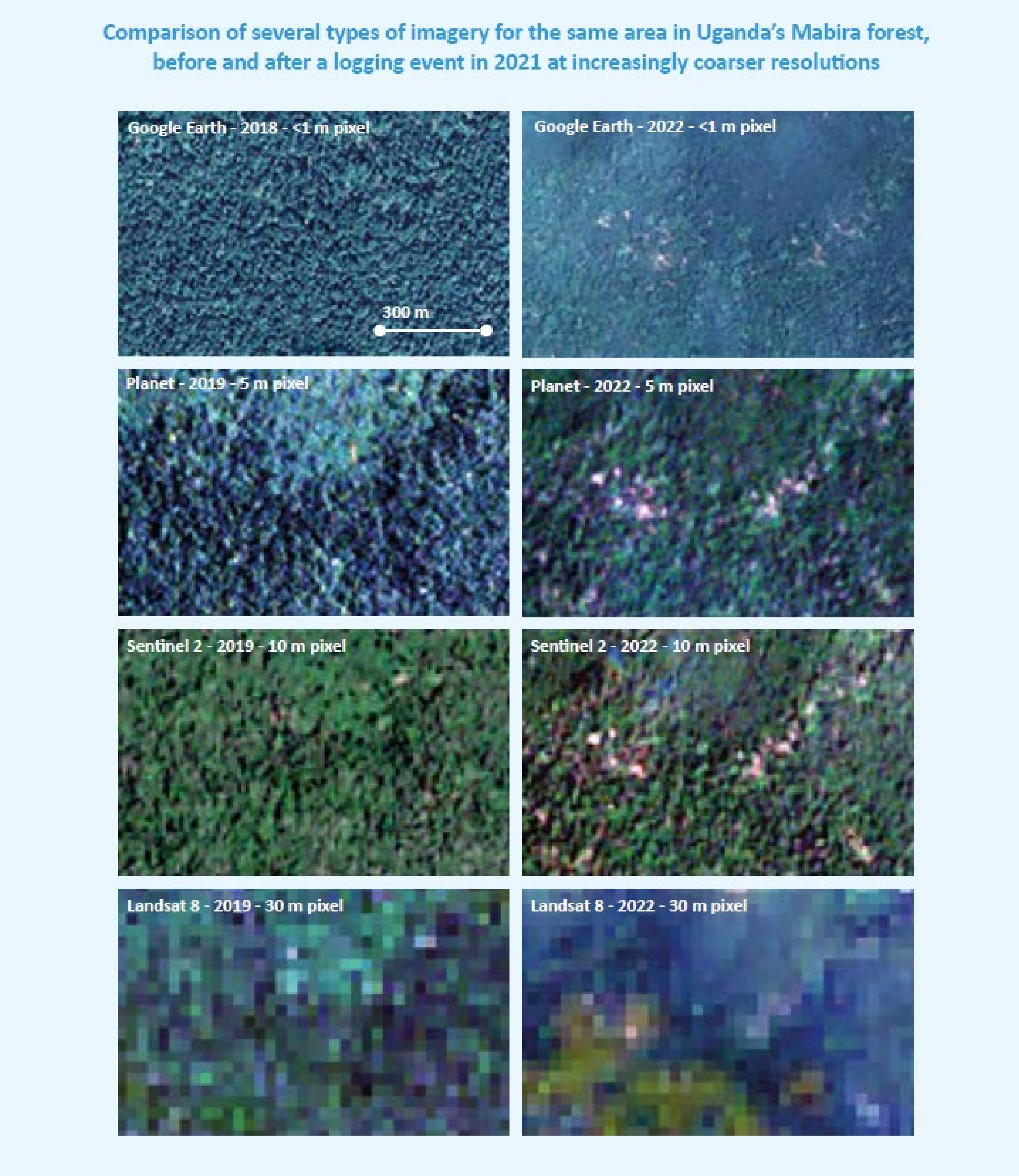
Un9 **Outdated methodological basis:** The latest version of the methodology was published in 2020, but the methodology only refers to the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003 report and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories are neither included in the references nor referred to in the respective sections. This is in particular a key omission as the revised version includes project activities on peatlands and for wetland restoration for which emission estimation methods are only properly covered by the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. 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**.

Un10 **Specific guidance missing for remote sensing**: Module VMD0015 (V 2.2) requires that medium resolution remote sensing data shall be used and that the same source of remotely sensed data must be used within the period for which the baseline is fixed and the project (p. 9). It is possible to change the source of satellite images if higher resolution sources become available. The methodology does not provide more specific guidance related to the determination of the forest areas but includes a reference to an outdated version of the GOFC-GOLD sourcebook for REDD. 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. VM0007 limits the data to medium resolution imagery from Landsat with 30 m resolution. Figure 3 shows the difference in the quality of detection of logging events. Landsat 30 m pixels are the pictures in the lowest row. 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**.

OE12 **Insufficient guidance for ground truthing*:*** VM0007 requires remote sensing data in combination with GIS data collected during ground truthing but does not provide specific guidance how ground truthing of remote sensing data should be implemented. It is not mentioned that there should be direct field observations used for ground truthing and checks 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**.

Un11 **Insufficient guidance on forest stratification*:*** The methodology does not provide specific guidance on stratification of forest areas. Stratification is mentioned, but it is left to project proponents how exactly this is implemented. Stratification is key for enhanced accuracy in large project areas, and it is important to link the detected areas of the forest strata with the appropriate biomass factors for the strata. Without further 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.**

Figure 3 Example demonstrating the comparison of remote sensing images to detect logging in a forest in Uganda



Source: Neeff et al. (2023)

OE13 **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).

The VCS module VMD0001 provides a 'priority' list for the type of equations that may be used. The sources provided are all based on older publications. 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.

While the module aims to prioritize the use of equations that are more specific to the project context, in practice, the provisions still leave room for project developers to select among different equations and to choose rather general pan-tropical equations. The module also provides a specific approach to validate the sources used by project developers. However, the validation approach uses generic, biomass expansion factors for which the data sources or their scope are not indicated. In our assessment, drawing on values provided by the IPCC, the use of these biomass expansion factors could tolerate an overestimation of at least 20%. Given that the uncertainty and variability in results from allometric equations is large and given that the limitations with the prioritization and validation approach, there is a risk that project developers can pick equations that lead to the determination of larger biomass carbon stocks.

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 methodology and module VMD0001 also do not account for the uncertainty of allometric equations; they do not require project developers to make any deductions for the uncertainty range or to select those equations that would lead to more conservative estimates. The flexibility in choosing between different equations and the lack of accounting for the uncertainty is therefore likely to lead to project developers choosing equations that result in higher carbon stocks, leading to overestimation of total credited emission reductions. Given that VMD0001 provides for a clearer prioritization of data sources, we deem this risk to be lower than for the methodologies VM0006, VM0009 and VM0015. The fraction of projects affected by this issue is **unknown**. Where this issue materializes, the degree of overestimation is estimated to be **low to medium** (up to 30%). The variability in the degree of overestimation among projects is likely to be **high**.

OE14 **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 VM0007 explains that it is preferable to use detailed data collected in the area, followed by using globally forest type-specific or eco-region-specific data and references to the IPCC Good Practice Guidance for LULUCF. 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**.

OE15 **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. This provision leaves room for project developers to select values that lead to higher estimates. For example, the provision would allow project developers to pick the value of 0.49 for wood in tropical forests from Table 4.3 in Volume 4 of the 2006 IPCC Guidelines. This value is based on a single study – rather than more recent and comprehensive information that has become available since – and would, in most instances, lead to an overestimation of emission reductions (e.g., by 7.5% compared to the best estimate for tropical trees determined by Martin et al. 2018). 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 VM0007

The methodology estimates the following sources of leakage:

1. **Activity Shifting due to Avoiding Planned Deforestation**: This relates to the estimation of GHG emissions due to activity shifting leakage from projects preventing planned deforestation. Activity shifting must be assessed using the module "Estimation of Emissions from Activity Shifting for Avoiding Planned Deforestation/Forest Degradation and Avoiding Planned Wetland Degradation" (LK-ASP).

2. **Activity Shifting due to Avoiding Unplanned Deforestation:** This relates to the estimation of carbon stock changes and GHG emissions related to unplanned deforestation and degradation activities displaced outside the project boundary. Activity shifting must be assessed using the

module “Estimation of Emissions from Activity Shifting for Avoiding Unplanned Deforestation/Forest Degradation and Avoiding Unplanned Wetland Degradation” (LK-ASU).

3. **Market leakage**: Consideration of market leakage is confined to any decrease in timber, fuel wood, or charcoal production relative to the baseline. Market leakage must be assessed using the module ‘Estimation of emissions from market effects’ (LK-ME).

4. **Emissions from leakage prevention measures**: This relates to emissions caused by measures to prevent leakage. If these measures lead to a significant increase in GHG emissions, then leakage must be accounted for using the T-SIG tool unless deemed insignificant. Emissions from any fertilizer use must be determined using the CDM TOOL07.

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

OE16 **No accounting for market leakage due to agricultural activities:** For avoided unplanned deforestation projects, the methodology requires market leakage deductions to be applied only when timber, fuelwood, or charcoal production are identified as deforestation drivers. For avoided planned deforestation projects. This approach fails to consider other important market-driven deforestation drivers. Though large-scale commercial agriculture is not relevant for avoided unplanned deforestation activities, but rather planned avoided deforestation projects, illegal conversion of forest land by small-holders for agriculture is an important driver for deforestation in many areas. If such activities would occur in the baseline scenario but are prevented under the project, this could induce higher levels of agricultural production elsewhere and thus lead to deforestation. Limiting the consideration of market leakage to timber, fuelwood or charcoal production could thus lead to underestimation of the actual impact of market leakage and overestimation of total credited emission reductions. As it is not known for how many projects these other drivers such as agriculture are relevant, the number of projects affected by this issue is **unknown**. The degree of overestimation is difficult to estimate and therefore also considered **unknown**. The variability in the degree of overestimation among projects is deemed to be **high**, as the materiality of such leakage may strongly vary between projects.

OE17 **Flexibility in determining baseline deforestation rates in the leakage belt:** To determine leakage from activity shifting, the methodology observes deforestation against a baseline in a leakage belt. The baseline deforestation rate in the leakage belt can be estimated using three different options: (a) using a historical deforestation trend that is determined through a linear regression of historical data; (b) a deforestation projection that uses data from publicly available business plans or similar documentation; and (c) the average historical deforestation during the five years before the project start (if the other two options are not applicable). This approach provides considerable flexibility to project developers to select an approach that leads to high baseline deforestation rates in the leakage belt. This is likely to lead to underestimation of the leakage effects and overestimation of total credited emission reductions. We estimate that this affects a **high** fraction of projects. The degree of overestimation is **unknown**. The variability in the degree of overestimation among projects is estimated to be **high**.

OE18 **Flexibility in choosing key parameters to determine market leakage:** The module VMD0011 offers project developers considerable flexibility to choose between different data sources for key data to determine leakage effects. For example, a key parameter affecting overall leakage deductions is the ‘mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type' (PM_{LFT}). For this parameter, the module does not specify which region should be considered, potentially allowing project developers to select a geographical delineation that results in a higher factor (e.g., choosing between the country or a sub-national jurisdiction). Likewise, the methodology offers project developers multiple choices which data they may use, including peer-reviewed published sources, official government data and statistics or original field managements. Similar flexibility is provided to several other data in the calculation. This is likely to lead to an underestimation of leakage effects and overestimation of total credited emission reductions. This issue is estimated to apply to a **high** fraction of projects. The degree of overestimation is estimated to be **low to medium** (up to 30%). The variability in the degree of overestimation is estimated to be **high.**

Un12 **Uncertainty in market leakage deduction discount factors:** The deductions used to account for market leakage (20% to 70%) broadly correspond to the range of market leakage expected to occur according to the literature (see discussion further above). The degree of market leakage is however associated with considerable uncertainty. This uncertainty is not accounted for by the methodology choosing a conservative approach (e.g., by using default values that are on the side of overestimating leakage). This issue affects **all** projects. As the uncertainty of leakage emissions is high and as they can make up a significant share of the emission reductions, we estimate that this introduces **medium to high** uncertainty to the total credited emission reductions. The variability among projects is estimated to be **high**.

OE19 **No accounting for international leakage**: The methodology does not account for any international leakage but limits the consideration of leakage to national boundaries. International leakage may, however, occur if projects are implemented nearby the borders of a country or if projects reduce the supply of commodities with globally interconnected markets (e.g., 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. Given that the definitions of the methodology do not preclude large-scale illegal deforestation for the purpose of producing agricultural commodities, ignoring international leakage is likely to 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**.

UE9 **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 3 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 1 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: Lack of clarity of the methodology	All	Unknown	Unknown
OE2: Lack of clarity regarding which emissions sources and carbon pools must be considered	High	Low to Medium	High
OE3: The determination of significance of carbon pools and leakage sources is unclear and is not required for emission sources	Unknown	Unknown	Unknown
OE4: Factors determined to be insignificant can be excluded without any limitations and project developers may choose from two methods to determine significance	Unknown	Low to Medium	High
OE5: Flexibility in choosing the approach for estimating the baseline for avoiding unplanned deforestation	High	Unknown	Unknown
OE6: Flexibility in the selection of the reference region for unplanned	High	High	High

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%.

deforestation projects for baselines using historic deforestation rates			
OE7: Flexibility in the selection of the reference region for unplanned deforestation projects for baselines using the population driver approach	High	High	High
OE8: Use of an exponential population growth rate	All	High	Unknown
OE9: Overestimation due to changes in intent of deforestation	Unknown	High	Unknown
OE10: Assumption of a likelihood of deforestation of 100%	Unknown	High	Unknown
OE11: Lack of appropriate definitions of forest, deforestation and degradation	All	Unknown	High
OE12: Insufficient guidance for ground truthing	High	Unknown	Unknown
OE13: Flexibility in choosing allometric equations	Unknown	Low to Medium	High
OE14: Flexibility in determining belowground biomass	High	Low	High
OE15: Overestimation of the carbon fraction in biomass	High	Low	High
OE16: No accounting for market leakage due to agricultural activities	Unknown	Unknown	High
OE17: Flexibility in determining baseline deforestation rates in the leakage belt	High	Unknown	High
OE18: Flexibility in choosing key parameters to determine market leakage	High	Low to Medium	High
OE19: No accounting for international leakage	Unknown	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: Belowground tree biomass is identified as an optional pool	Unknown	Low	Unknown
UE3: Deadwood is an optional source	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: Emissions from biomass burning are identified as an optional source in the baseline	Unknown	Low	Unknown
UE7: Methodology does not consider CH_4 emissions from livestock	Unknown	Low	Unknown
UE8: N_2O emissions from the application of fertilizer are optional unless fertilizer use increases due to the project	Unknown	Low	Unknown
UE9: No accounting of any negative leakage	Low	Low	High
Elements with unknown impact			
Un1: Inclusion of CO_2 from the combustion of fossil fuels is unclear but interpreted to not be required	Unknown	Low	Unknown
Un2: Flexibility in choosing the modelling approach for deforestation risk mapping	High	Unknown	Unknown
Un3: Uncertainty in the models used to establish the risk map	All	Unknown	Unknown
Un4: Uncertainty in determining the DP	All	High	Unknown
Un5: Flexibility in choosing the proxy area	Unknown	High	Unknown
Un6: Uncertainty in determining post deforestation carbon stocks	All	Unknown	Unknown
Un7: Limited guidance for analyzing deforestation rates in the proxy area	All	Medium	Unknown
Un8: Overall uncertainty assessment	All	Unknown	Unknown
Un9: Outdated methodological basis	All	Unknown	Unknown
Un10: Specific guidance missing for remote sensing	High	Unknown	Unknown
Un11: Insufficient guidance on forest stratification	All	Unknown	Unknown
Un12: Uncertainty in market leakage deduction discount factors	All	Medium to High	High

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 the case of unplanned deforestation projects, the most important issues contributing to a likely overestimation of baseline emissions are the flexibility provided to project developers for choosing the approach to calculate baseline emissions (i.e., historical or population driver approach) (OE5) and the flexibility in choosing the reference region (OE6 and OE7). Specific to the population driver approach, the possibility to use an exponential population growth rate also contributes to potential overestimation (OE8). In the case of planned deforestation projects, two issues contribute to a potential overestimation of emission reductions: a potential change in the intent to deforest by the deforestation agent in the time before the project start date (OE9) and the assumption that the likelihood of deforestation for a given area is 100% (OE10).

We also find that leakage effects are likely to be underestimated, in particular due to the flexibility provided to project developers in determining the leakage belt (OE17) and in choosing key parameters to determine market leakage (OE18). 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 (OE11 to OE14). We also note that the exclusion of some carbon pools and emission sources may lead to underestimation for some projects (UE1 to UE6) but this underestimation is estimated to be significantly smaller than the risks of overestimation.

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