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. The preparation of this document was funded through the European Union's HORIZON EUROPE Research and Innovation Programme under grant agreement number 101137625 (ACHIEVE).

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Sub-criterion:	**1.3.2 Robustness of the quantification methodologies applied to determine emission reductions or removals**
Project Type:	**Avoided unplanned deforestation**
Quantification methodology:	**VCS Methodology VM0048, Version 1.0** **Reducing Emissions from Deforestation and Forest Degradation**
Assessment based on carbon crediting program documents valid as of:	**1 April 2024**
Date of final assessment:	**2 July 2024**
Score:	**1**

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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 VM0048. Reducing Emissions from Deforestation and Forest Degradation. Version 1.0,27 November 2023. https://verra.org/methodologies/vm0048-reducing-emissions-from-deforestation-and-forest-degradation-v1-0/

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 (2024): VCS Tool VT0007. Unplanned Deforestation Allocation (UDEF-A). Version 1.0, 21 February 2024. https://verra.org/wp-content/uploads/2024/02/VT0007-Unplanned-Deforestation-Allocation-v1.0.pdf

4 Verra (2023): VCS Module VMD0013. Estimation of greenhouse gas emissions from biomass and peat burning (E-BPB). Version 1.3, 27 November 2023. https://verra.org/wp-content/uploads/2023/11/VMD0013-Estimation-of-Greenhouse-Gas-Emissions-from-Biomass-and-Peat-Burning-E%E2%80%93BPB-v1.3.pdf

5 Verra (2024): VCS Module VMD0055. Estimation of Emission Reductions from Avoiding Unplanned Deforestation, Version 1.0, 20 February 2024. https://verra.org/wp-content/uploads/2024/02/VMD0055-Estimation-of-Emission-Reductions-from-Avoiding-Unplanned-Deforestation-v1.0-2024.02.20-update.pdf

6 Verra (2023): VCS Program Definitions. Version 4.4, 29 August 2023. https://verra.org/wp-content/uploads/2023/08/VCS-Program-Definitions-v4.4.pdf

7 Verra (2023): VCS Methodology Requirements. Version 4.4, 4 October 2023. https://verra.org/wp-content/uploads/2023/08/VCS-Methodology-Requirements-v4.4-updated-4-Oct-2023.pdf

8 Verra (2023): VCS Registration and Issuance Process. Version 4.4, 4 October 2023. https://verra.org/wp-content/uploads/2023/08/Registration-and-Issuance-Process-v4.4-last-updated-4-Oct-2023-watermark.pdf

9 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

Verra also announced that it plans to update several methodologies, modules and tools applicable to avoided deforestation projects, as part of its forest strategy.[1]

Assessment outcome

The quantification methodology is assigned a score of 1.

Note that in contrast to other methodologies assessed by CCQI, the methodology VM0048 has not yet been applied to any projects as of 1 April 2024. Therefore, this assessment is only based on an analysis of the methodology, without practical experience and literature on how it is applied in

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[1] See, for example: https://verra.org/wp-content/uploads/2024/02/Forest-Carbon-Strategy-15-Feb-2023.pdf

practice. The findings are therefore preliminary and may need to be updated once more experience with the implementation of the methodology becomes available.

Further note that all avoided unplanned deforestation registered under Verra using older methodologies (VM0006, VM0007, VM0009 ad VM0015) are required to transition to this new methodology. When all projects have completed the transition, these older methodologies will be inactivated by Verra.

Justification of assessment

Project type

This assessment refers to the following CCQI project type:

“Activities to avoid deforestation that is driven by multiple, mostly local agents. The deforestation occurs as a result of socioeconomic forces, such as subsistence agriculture of local communities, encroaching roads, or illegal logging. In addition, forest degradation may be reduced. Projects usually combine different activities to reduce deforestation, such as improving agricultural practices of local communities, providing alternative livelihoods, instituting patrols or assisting with land tenure reform. The activities are implemented on a dedicated project-level geographical area (not at jurisdictional level). The project type reduces emissions by avoiding the loss of forest carbon stocks.”

The CCQI project type, as described above, is applicable to the methodology.

The methodology VM0048 is a framework that is to be used together with several modules and tools. As of 1 April 2024, the methodology VM0048 is only applicable to avoided unplanned deforestation, for which module VMD0055 must be applied. A module for Avoiding Planned Deforestation and requirements for Avoiding Unplanned Forest Degradation are under development (with associated leakage adjustments). In the future, the methodology will thus also become applicable to these activities.

This assessment does not apply to projects that are nested under a jurisdictional carbon crediting program or where a government provides a jurisdictional baseline. In these instances, the conservativeness of the emission reductions strongly hinges on the conservativeness of this jurisdictional baseline, which is not evaluated as part of this assessment.

The methodology VM0048 and the module VMD0055 define unplanned deforestation as "deforestation of degraded to mature forests not legally authorized and documented for conversion". Planned deforestation is respectively defined as "deforestation on forest lands that are legally authorized and documented for conversion". In the VCS program definitions, "deforestation" is defined as "direct human-induced conversion of forest land to non-forest land" and forest is defined as "land with woody vegetation that meets an internationally accepted definition (e.g., UNFCCC, FAO, or IPCC) of what constitutes a forest, which includes threshold parameters, such as minimum forest area, tree height, and level of crown cover, and may include mature, secondary, degraded, and wetland forests". The VCS module VMD0055 further specifies that forest "must include woody vegetation with a canopy cover of between 10 and 30 percent, as used in the relevant country’s international reporting to the UNFCCC, or as otherwise officially elected as an applicable definition for use by climate change mitigation projects and programs." Moreover, the project boundary section of the VCS module VMD0055 specifies that the project area may only include "land qualifying as forest for a minimum of 10 years before the project start date". The module further specifies in its applicability conditions that "agents of deforestation in the baseline scenario clear the land for tree harvesting, settlements, roads, unsanctioned expansion of roads or other infrastructure, agricultural crop production, ranching or aquaculture" and that projects that "harvests trees to generate income, fiber or fuel" are not eligible. Several further provisions in the module VMD0055 indicate that drivers of deforestation can be “commercial” or “subsistence” and that drivers may include “prices of agricultural, timber, mineral or other commodities”.

Un1 **Lack of clarity of definitions:** The definitions in the methodology and the documents referred to above lack some clarity. The methodology VM0048 and the module VMD0055 lists in various places different drivers of deforestation that may be considered but the descriptions of possible drivers are not fully consistent. While the definition includes “mature, secondary, degraded, and wetland forests, the methodology VM0048 further specifies that forest “must include woody vegetation with a canopy cover of between 10 and 30 percent”. A 30 percent canopy cover is far too low for mature, non-degraded forests. The 30 percent reads as a maximum canopy cover; the definition thus seems to exclude mature, non-degraded forests – which may not be intended but should be clarified. In our assessment, the lack of clarity of creates some uncertainty how the methodology would be interpreted. This applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

Selection of carbon pools and emission sources for calculating emission reductions or removals

The methodology VM0048 describes in sections 5.2 and 5.3 various carbon pools and emission sources that must be included in the boundary of projects implementing VM0048 as well as pools and sources that are optional to include, sometimes specifying conditions under which they must or may be included or excluded. In addition, the methodology requires assessing the significance of emission sources and carbon pools, following the approach set out in Appendix 1 to the methodology. According to this procedure, project and leakage emission sources (including emissions from carbon pools) are ranked according to their significance. The sources or pools contributing the last 5% of total emissions may be excluded.

The combination of these provisions does not provide clarity to resolve which emission sources and carbon pools must be accounted for. The methodology is not clear on the following points: (a) whether the analysis in Appendix 1 must be carried out for all emission sources and carbon pools (including those that are mandatory to be included) or only for those that are optional to include; (b) whether emission sources and carbon pools that are mandatory for inclusion according to section 5.2 and 5.3 may be excluded if procedure in Appendix 1 concludes that they are negligible; and (c) whether carbon pools and emission sources labeled as “optional” in sections 5.2 and 5.3 of the methodology may be excluded if the procedure in Appendix 1 leads to the conclusion that they are not negligible. Based on information provided by Verra to CCQI, in the following we interpret the methodology to mean that optional pools and sources can be excluded only if determined to be negligible.

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

Table 1 Assessment of sources, sinks, reservoirs

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Carbon pools		
Aboveground tree biomass	Included for baseline and project	Major carbon pool affected by projects.
Aboveground non-tree biomass	Post-deforestation carbon stocks must be included in the baseline; May be conservatively excluded from the “forest carbon stocks”	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 scenario and exclusion in the project scenario is likely to be conservative.
Belowground tree biomass	Included for baseline and project	Major carbon pool affected by projects.
Belowground non-tree biomass	Optional, methodology states the potential emissions are negligible	Belowground non-tree biomass there 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	Optional, methodology states it is conservative to exclude	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 then 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	Optional, methodology states it is conservative to exclude	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 (currently not allowed under VMD0055), otherwise optional. Methodology states that it is conservative to exclude this pool if projects are implemented on non-wetland areas.	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)	Optional if timber harvest is determined to be negligible in the baseline. Based on determinations from appendix 1.	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 only allows exclusion if timber harvest is deemed negligible in the baseline. This is appropriate.
Emission sources		
Emissions from biomass burning	CO_2 included. However, 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. 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 are optional in baseline and included in the project scenario.	Conservative to exclude in the baseline scenario, but can be an important emissions source in project scenario.
Combustion of fossil fuels	CO_2 may be excluded when determined to be negligible in the baseline. CO_2 from combustion of fossil fuels related to leakage prevention activities are "always considered insignificant", but CO_2 from other activities (e.g., monitoring, patrolling) must be demonstrated to be negligible to be omitted.	Exclusion may lead to uncertainty because emissions from combustion may increase or decrease as result of project activities relative to baseline. Under the baseline scenario, emissions from combustion of fuel in harvesting equipment and fuel crop production equipment fuel occurs.

		In project scenarios emissions may increase or decrease from equipment used in monitoring or patrolling the project area.
	CH_4 and N_2O are excluded, 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	Optional in baseline, must be included if fertilizer use increases due to the project. May be excluded from the baseline if determined to be negligible. If excluded from the baseline and fertilizer use does not increase due to the project, then it may be excluded.	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.

OE1 **Lack of clarity regarding which emissions sources and carbon pools must be considered:** The lack of clarity of the methodology on which emission sources and carbon pools must be considered, as described in the second paragraph of this section above, creates some room for interpretation. We see a risk that project developers and validation and verification bodies may interpret the methodology in ways that could lead to higher 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 **low** (less than 10%). The variability in the degree of overestimation among projects is **unknown**.

OE2 **Determination of significance of emission sources allows project developers to choose among multiple methods**: The methodology in Appendix 1 of VM0048 provides a procedure to determine the significance of project and leakage emission sources and to allow project developers to exclude those sources that amount to as much as 5% of total project and leakage emissions. The approach provides leeway to project developers regarding how the significance is estimated. Provision 2)a) in the Appendix states that "estimation must be based on site/project-specific data, scientific peer-reviewed literature and/or the most recent default emission factors provided by IPCC." Project developer could pick from these methods 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). For example, the determination of whether harvested wood products are significant depends on many assumptions, including the potential uses of wood products in the baseline scenario. As project developers have incentives to make favorable assumptions, this could cause overestimation of total credited emission reductions. The number of projects affected by this is **unknown**. For those projects where this issue materializes, the impact on total credited emissions reductions is estimated to be **low**[2] (less than 10%). The variability in the degree of overestimation among projects is **unknown**.

UE1 **Soil carbon is identified as an optional source,** except when project activities are implemented in wetlands (which are not eligible to apply the methodology at this time)**.** 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**.

UE2 **Litter is identified as an optional source:** Litter is anticipated to decrease in the baseline scenario resulting from deforestation. Given that measuring litter would increase the emission reductions that could be quantified as project impact it is conservative to exclude litter. This 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**.

UE3 **Emissions from biomass burning is 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 VM0048 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**.

UE4 **Above ground non-tree biomass is optional to include in the project’s forest carbon stocks**: In the baseline, deforestation would result in a lower amount of non-tree biomass than in the project with exclusion leading to underestimation. This issue applies to projects that opt to exclude above ground non-tree biomass. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE5 **Deadwood is an optional pool**: Naturally occurring deadwood (both standing and lying) is likely to be lower in the baseline scenario than in the project scenario. Therefore, exclusion of this carbon pool is likely to lead to underestimation of emission reductions. This issue applies to projects that opt to exclude deadwood. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

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[2] The potential harm of this provision is somewhat limited by the methodology in Appendix 1 which requires all pools and sources of emissions to be accounted for, up to 95% of the total emissions impact of the project. While the flexibility in methods may allow the exclusion of pools and sources representing more than 5% of the actual project impact, this provision is determined to reduce the risk of gaming.

UE6 **Methodology does not consider emissions from livestock:** Livestock emissions within the project boundary are likely to decrease compared to a baseline scenario where deforestation occurs to enable livestock production. Excluding livestock emissions from baseline and project is therefore likely to result in underestimation of emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

UE7 **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**.

Un2 **Methodology does not require CO_2 from the combustion of fossil fuels to be included**: 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 the under- or over-estimation effect is greater. The number of projects impacted by this issue is **unknown**. For those projects where this issue materializes, this issue introduces a **low** (less than 10%) degree of uncertainty to the estimation of total credited emission reductions. The variability in the degree of uncertainty is **unknown**.

Determination of baseline deforestation levels

In the following, we first provide an overview of general challenges regarding the determination of baseline deforestation levels. We then turn to a detailed assessment of VM0048.

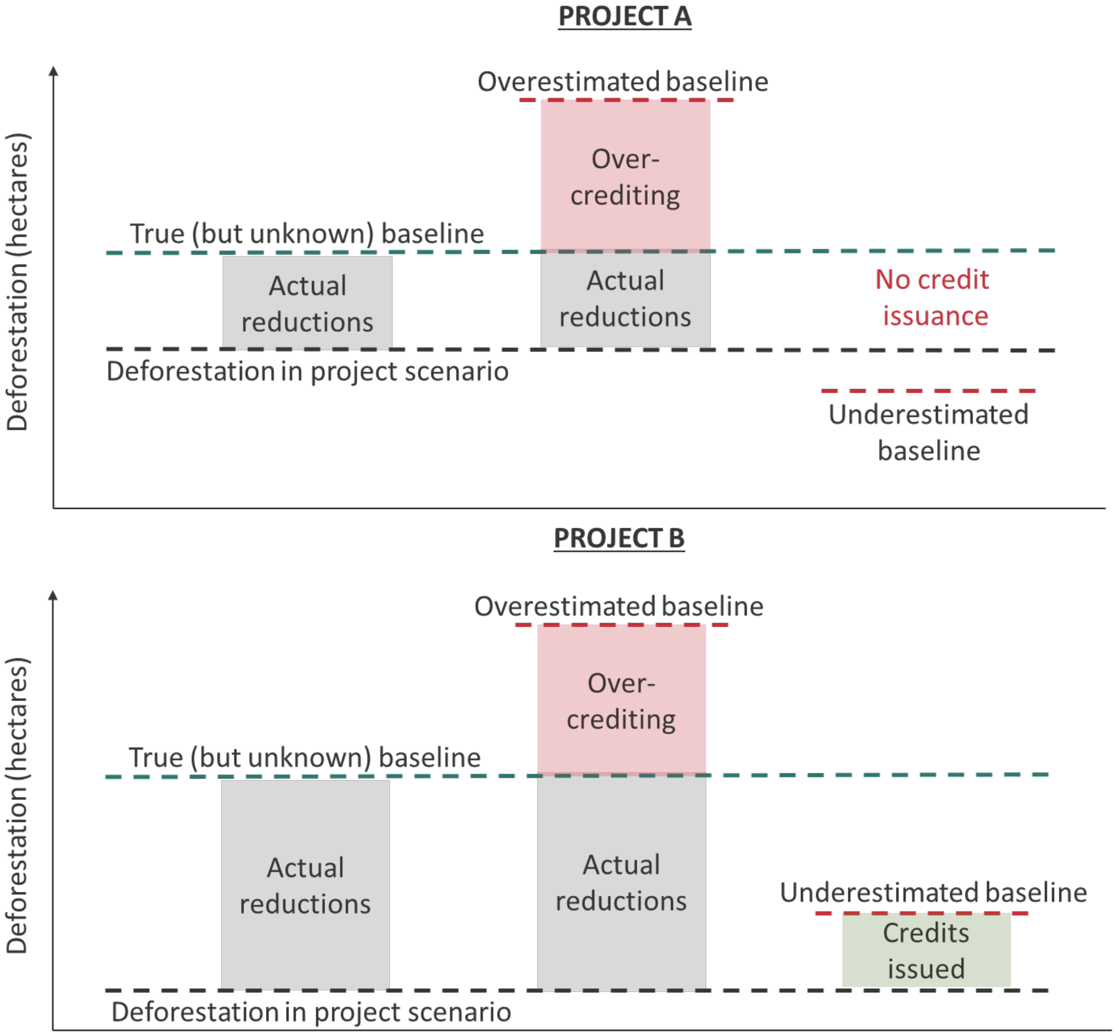
General challenges in establishing baselines for avoided deforestation projects

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.

Assessment of VM0048

The newer methodology VM0048 was introduced by Verra in November 2023 and will replace the older VCS methodologies (VM0006, VM0007, VM0009 and VM0015). The new methodology VM0048 is a major evolution compared to the previous methodologies and addresses some of the issues identified with them, as summarized above. A key change is that the new methodology determines baseline deforestation rates for an entire jurisdiction and allocates the jurisdictional deforestation data across the jurisdiction based on deforestation risk. This approach allows for consistency with jurisdictional targets (e.g., NDCs) or crediting levels (e.g., jurisdictional crediting approaches). A second important change is that VM0048 strongly reduces the flexibility for project developers in establishing baseline deforestation rates. For a given project area, the baseline deforestation rate will be determined by Verra and provided to the project developers.

Under the methodology VM0048, the module VMD0055 and tool VT0007, the determination of baseline emissions involves the following main steps:

1. **Estimation of baseline deforestation levels at jurisdictional level:** Module VMD0055 requires determining a "jurisdictional average annual rate of unplanned deforestation" for an entire jurisdiction, referred to as 'activity data' in the methodology. This deforestation rate is determined based on the average rate of deforestation observed in the jurisdiction in a historical reference period of about ten years (images from within ±365 days from the start and end date of the historical reference period may be used for the analysis depending on availability of remote sensing images (see VMD0055, p. 111).[3] The methodology thus implicitly assumes that the average historical deforestation rate in the jurisdiction will continue at the same rate in the future. The jurisdictional baseline activity data is provided by Verra and developed by data service providers for Verra. The work carried out by independent service providers will be assessed by independent experts. The total area of deforestation in the historical reference period is determined using high-resolution remote sensing imagery interpreted by humans. Starting from a wall-to-wall map of the jurisdiction, a representative sample of plots is taken. The land cover assessment is then done for the representative sample. The statistical uncertainty must not be greater than 20%. The estimated area of unplanned deforestation is adjusted downwards to account for statistical uncertainty if the uncertainty lies between 10% and 20%. No uncertainty deduction is applied if the sampling uncertainty is smaller than 10%. As a final step, the total historical deforestation over the historical reference period is then annualized.
2. **Construction of a map of future deforestation risk (risk map)**: The tool VT0007 is used to build a deforestation risk map for the jurisdiction. This includes the development of "benchmark risk map", which uses a simplified approach and considers only two parameters to identify deforestation risk: historical deforestation and distance to forest edge. In addition, at least two alternative approaches towards the risk map must be implemented, which may consider other parameters, such as existence of roads or the slope of the area. The median absolute error between modelled deforestation density and actual deforestation is used to assess and compare the accuracy of the alternative risk maps with the benchmark risk map. Alternative risk maps are candidates for use as the final risk map if they exhibit lower median absolute error than the benchmark map. This approach includes the following sub-steps:

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[3] The duration of the historical reference period of ten years is not explicitly mentioned in VM0048, VMD0055 or VT0007. We assume it to be 10 years (± a specific number of days depending on imagery used for the analysis of historic activity data) under consideration of the following sources:
- The definitions section in VMD0055 states that the historical reference period is "a fixed period of time (…), the duration of which is set out in the VCS Methodology Requirements".
- The VCS Methodology Requirements (version 4.4 from 4 October 2023, p.32) state that the analysis of "past patterns" of deforestation "shall be based on historical factors over **at least** the previous 10 years" (emphasis added). Note that VMD0055 specifies that images within a period of ±365 days from the start and end date of the historical reference period may be used. Thus, the reference period could also be shorter than ten years, which would not be in line with the Verra Methodological Requirements.
- The Verra website and introductory webinars to the methodology mention a ten-year historical reference period (https://verra.org/methodologies-main/technical-background-note-new-redd-methodology/, https://www.youtube.com/watch?v=YhXg9zOX3As, https://www.youtube.com/watch?v=1nlEiBgYJtc)

a. In a first sub-step, a “forest cover benchmark map” (FCBM) is developed. This benchmark map is a raster map of the jurisdiction, developed based on imagery with a minimum resolution of 30m x 30m. Images from three points in time during the historical reference period are analyzed, namely the beginning, the middle, and the end. Each map contains binary information where land is classified as forest or non-forest. This allows determining changes from forest to non-forest land between these points. This results in 8 forest transitions (see Appendix 1.4.3 step 1), which are then further grouped into four “simplified classes” (stable forest, stable non-forest, deforested in the first half of the historical reference period, deforested in the second half of the historical reference period). The information from the forest benchmark map is used to calibrate and test the prediction of future deforestation. Observations at the start and the middle of the reference period are used for calibration, and observations at the middle and the end of the reference period are used for testing the quality of the prediction.

b. In a second sub-step, the forest cover benchmark map is used to assign “vulnerability classes” to the forest land within the jurisdiction, representing different degrees of vulnerability to deforestation. Distance to forest edge is the only covariate used for determining vulnerability in the benchmark risk map. The forest cover benchmark map is used to identify the distance to forests edge at which 99.5% of deforestation in the historical reference period has occurred. This distance is referred to as the negligible risk threshold. All relevant forest areas within the jurisdiction are assigned vulnerability classes, depending on their distance to the forest edge. Vulnerability is defined on an ordinal scale of 30 classes. Areas close to an edge get assigned the highest vulnerability (30). The lowest class (1) is assigned to land areas that lie beyond the negligible risk threshold and are still within the jurisdiction. Areas that are not considered forest in the analysis are assigned 0. In addition to the benchmark method based on distance to forest edge, at least two alternative vulnerability maps that incorporate jurisdiction-specific risk factors must be developed. Like the benchmark approach, alternative vulnerability maps should also be scaled from 1 to 30. Any classification scheme is acceptable as long as vulnerability is scaled from 1 to 30, with 1 denoting the lowest risk class and 30 the highest.

c. In a third sub-step, the benchmark and alternative maps of vulnerability classes are each combined with a map of administrative divisions, to create so-called “modelling regions”. Each modelling region is a unique combination of vulnerability class and an administrative division.

d. The fourth step is to calculate the relative frequency of deforestation. A relative frequency is calculated by counting how many times an event of interest occurs and dividing it by the total number of possible events. In this methodology, the event of interest is whether deforestation occurred in a pixel. The total number of possible events are the pixels within a modeling region. The forest cover benchmark contains information on possible forest transitions, including deforestation, during the calibration and testing periods. The relative frequency of deforestation during the calibration period in each modeling region is applied to the corresponding modeling region in the period to be predicted, yielding a map of probabilities of deforestation in the prediction period. To determine an area of deforestation, the relative frequency is multiplied by the area of a pixel, resulting in the deforestation density (ha/pixel).

Sub-steps a to d are carried out two times for each candidate risk map (the benchmark and at least two alternatives). The first time is for model fitting to the calibration period data. The second time is for creating predictions on a test set, which are ultimately used for assessing risk map quality and map selection among the candidates.

A coarse grid, with a resolution equal to the median size of REDD projects within the jurisdiction, is established for both the calibration and testing periods to compare benchmark and alternative models. The amount of deforestation (in hectares) observed in both periods is tabulated. For both periods, median absolute error (MedAE) is calculated as the median of the absolute differences between actual and fitted deforestation across these grid cells, providing a summary measure of the error in hectares. The candidate that exhibits the lowest MedAE in both periods is selected as the final model.

After a risk map is selected from among the candidates, the sub-steps are carried out a final time to predict deforestation risk during the baseline validity period. When predicting for the baseline validity period, the model used to create the vulnerability map referenced in step b is fit using the same parameters as the selected candidate model. However, data spanning the entire historical reference period is used to fit this model. As a final step the total predicted deforestation is adjusted to not exceed the total deforestation assumed for the entire jurisdiction as determined in step 1 above. The resulting benchmark risk map will be publicly available.

3. **Allocation of deforestation activity data to projects based on the risk map:** The result of all previous steps is a predicted deforestation density for one year of the baseline validity period (ha/pixel/year) for all pixels within a jurisdiction. The methodology refers to the predicted deforestation density as the allocated risk. The portion of that risk corresponding to a project equals all pixels that fall within the project area polygon. A sum of values of all pixels is the baseline activity data of a project. Project proponents receive an allocation from Verra upon request and will have to pay a yet to be determined fee for this.
4. **Calculation of the project specific baseline emissions:** For calculating the project-specific baseline emissions, project proponents must stratify their project area and determine emission factors for each stratum. Then the pixels that fall within a specific stratum and allocated risk are determined. Overlying the map with the information on stratification and the map with the allocated risk allows multiplying the allocated risk with the emission factors of each stratum and calculating baseline emissions in tCO_2/year.

A baseline is valid for six years (e.g., from 1 January 2021 until 31 December 2026). Thereafter, new activity data, forest benchmark maps and risk allocations for the next “baseline validity period” will be provided by Verra and the data service providers.

Project developers are also required to determine a baseline scenario. This is done using an additionality analysis, which starts by identifying alternative land use scenarios that are consistent with existing laws and regulations. If there are none, the baseline scenarios to be considered include the continuation of pre-project land use, the project activity without financing from the voluntary market and similar activities to the project. Additionally, an investment analysis or a barrier analysis must be carried out to determine the baseline scenario. The project must analyze and describe the agents and drivers of deforestation of its baseline scenario.

The methodology VM0048, and the module VMD0055 and tool VT0007, aims to address several of the significant shortcomings identified with the previous VCS methodologies assessed by CCQI (VM005, VM0007, VM0009, VM0015). The most important improvement is that baseline data on avoided deforestation areas is provided by Verra. This considerably reduces the flexibility for project developers to make unrealistic assumptions about baseline deforestation rates. This flexibility is considered as the main cause of significant overestimation of emission reductions under the existing methodologies (Haya 2023, other references). A further improvement is the use of a shorter baseline validity period and thus more frequent updates of baselines. A third improvement is that uncertainty in the data used to establish baseline, including historical deforestation rates and emission factors (carbon per hectare) is considered and accounted for.

In the following, we assess potential sources of overestimation, underestimation or uncertainty with the methodology and its modules and tools. With regard to the establishment of the jurisdictional average annual rate of unplanned deforestation, we identify the following elements of possible overestimation, underestimation or uncertainty:

OE3 **Establishment of the jurisdictional baseline scenario:** For each six-year baseline validity period, the methodology establishes the jurisdictional baseline scenario as the average deforestation rates observed in a historical reference period of about 10 years. The methodology thus assumes that the average historical deforestation rates will continue for a period of six years. During this period, the methodology does not account for confounding or exogenous factors that may impact deforestation levels over time, which could result in higher or lower true (but unknown) baseline levels than observed historically. Any changes in confounding or exogenous factors would, however, be captured over time when establishing an updated baseline for a subsequent baseline validity period. The level of the calculated baseline also hinges on the which 10-year period is selected (i.e., what the start and end date of this period is), as there are often large interannual variations in the level of deforestation.

In assessing the conservativeness of this approach, we discuss four issues:

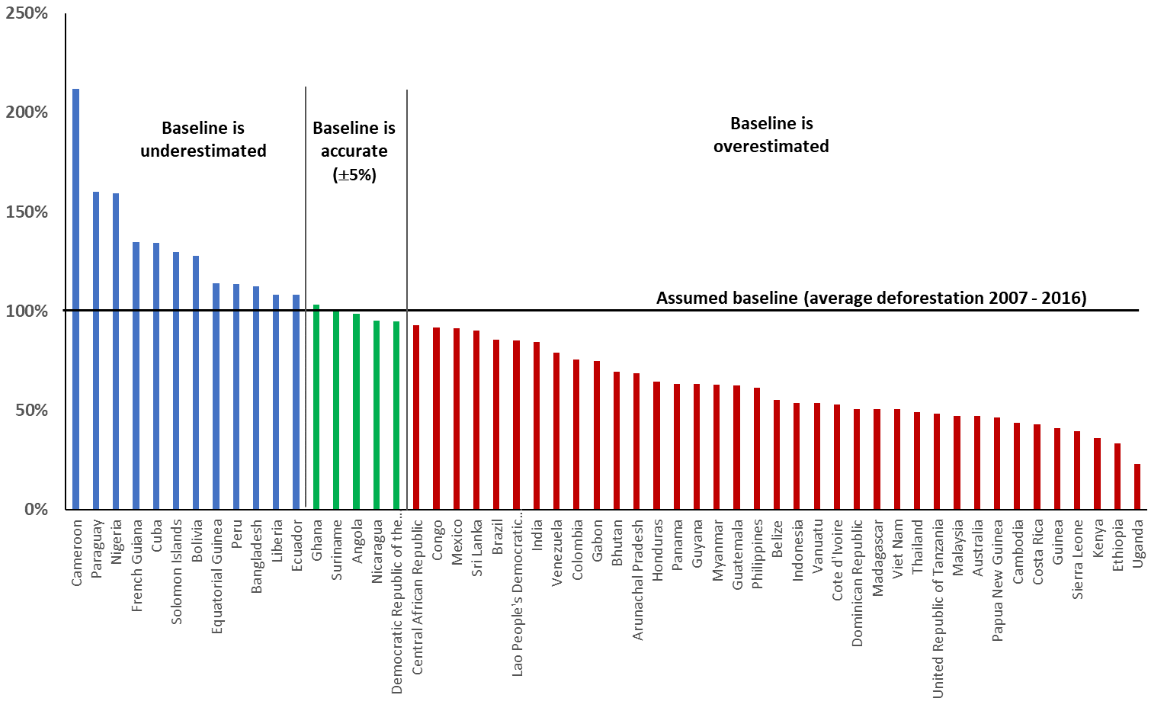
1. Uncertainty in short-term variations in deforestation levels;
2. Potential underestimation of baseline levels due to the impact of carbon crediting projects on deforestation in the historical reference period;
3. Impact of longer-term trends in deforestation levels;
4. Potential overestimation of baseline levels due to continued crediting even if no forest would be available anymore.

Uncertainty in short-term variations in deforestation levels

The available data suggests that deforestation levels are decreasing in some jurisdictions and decreasing in others. Often trends change over time. These short-term changes in individual jurisdictions introduce uncertainty in establishing the jurisdictional baseline.

Figure 2 illustrates the implications of such short-term variations in deforestation levels for 54 countries with tropical moist forests. In the figure, we use historical deforestation data from the Joint Research Centre (JRC) to compare for each country the actual deforestation levels observed in a hypothetical six-year baseline validity period from 2017 to 2022 (the latest available data) with the calculated baseline for the jurisdiction based on the average deforestation observed in the period 2007 to 2016. The figure shows that the baseline would be accurate (±5%) for five jurisdictions. For 12 jurisdictions, the baseline would be underestimated and for 37 jurisdictions it would be overestimated. The figure also shows that the deviation is significant for many jurisdictions. In the most extreme scenarios, the baseline could be 435% higher (Uganda) or 53% lower (Cameroon) than actually observed deforestation in the hypothetical baseline validity period. While there is uncertainty in these numbers, this illustrative example suggests that assuming historical deforestation data could lead in significant over- or underestimation of jurisdictional baseline deforestation levels for a given baseline validity period.

Figure 2 **Deforestation in 54 jurisdictions in a hypothetical baseline validity period from 2017 to 2022 compared to the assumed baseline based on deforestation in the period 2007 to 2016**



Source: Own illustrated based on data on direct and indirect deforestation from EU Joint Research Centre (https://forobs.jrc.ec.europa.eu/TMF/data#stats).

The risk of large uncertainty in a given baseline validity period may be mitigated by the fact that baselines are updated every six years. For example, a jurisdiction that has an overestimated baseline in the first baseline validity period might have an underestimated baseline in the subsequent period, depending on the deforestation trends in the jurisdictions. The deviations between the calculated baseline and the actual jurisdictional deforestation levels could thus be small when aggregating several baseline validity periods.

The uncertainty in establishing the jurisdictional baseline deforestation rates poses the risk that projects in those jurisdictions where the true (but unknown) baseline is lower than the calculated baseline have a competitive advantage over projects in regions where the true baseline is higher than the calculated baseline. As discussed above, large unaccounted uncertainty in baselines can undermine the overall portfolio of projects. This is because projects in jurisdictions with overestimated baselines will receive more carbon credits than their actual emission reductions and can thus offer these at relatively lower prices, whereas projects in jurisdictions with underestimated baselines receive fewer carbon credits and may not find buyers or may even fail, or not succeed, as they cannot generate sufficient revenues from carbon credits. This could lead to more carbon credits being generated from regions where the jurisdictional baseline is overestimated, and fewer carbon credits generated from regions with underestimated jurisdictional baselines. On the other hand, the location and success of projects may only partially be influenced by carbon credit revenues. Some projects may succeed even if they receive much fewer credits than their actual emission reductions. At this stage, it is difficult to assess how large this risk will be for VM0048, given that the location of projects and the jurisdictional baselines are not yet known.

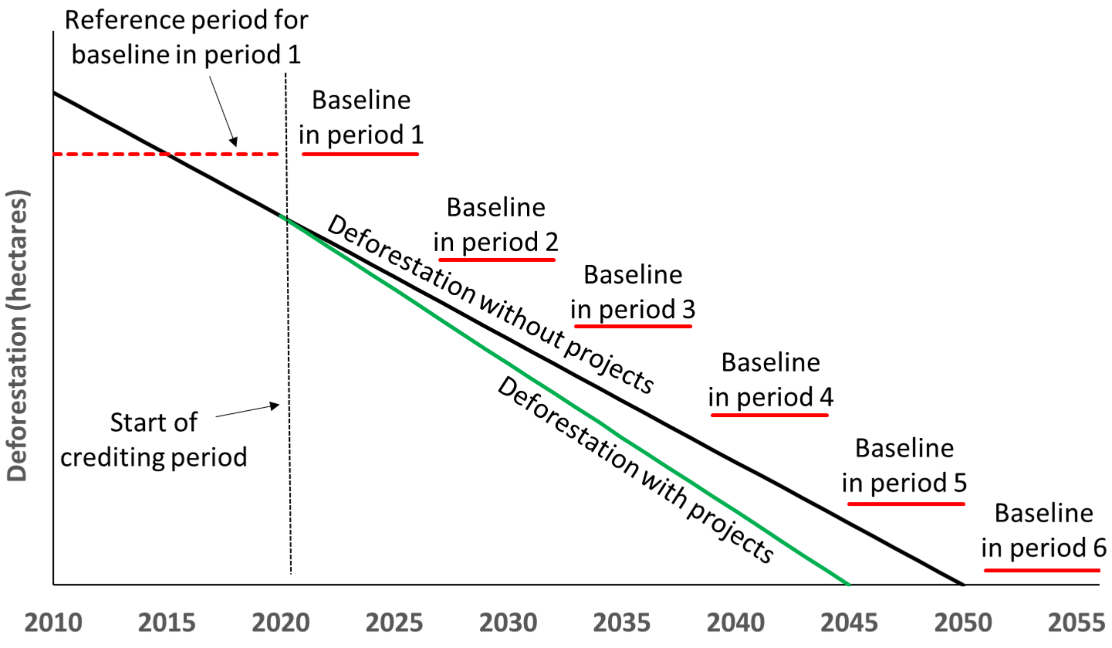
Underestimation of baseline levels due to the impact of carbon crediting projects on deforestation in the historical reference period

The methodology uses the average historical deforestation levels in a reference period of 10 years to establish the baseline deforestation levels for the subsequent six years. If carbon crediting projects are implemented in the historical reference period, their emission reductions are reflected in the historical data. In the absence of these carbon crediting projects, deforestation levels would be higher. This contributes to an underestimation of baseline deforestation levels. The degree of underestimation strongly depends on the impact of carbon crediting projects on overall deforestation levels in the jurisdiction. The larger their impact is, the larger is the underestimation of baseline deforestation levels (see discussion further below).

Impact of longer-term trends in deforestation levels

While deforestation rates are subject to short-term changes, as discussed above, an important question is how well the methodology captures any longer-term deforestation trends. In principle, the methodology captures longer-term trends, as the baseline is updated every six years. The trends are, however, only captured with a delay, due to the use of historical data from the past ten years to establish the baseline scenario.

Figure 3 Implications of using historical data to establish the jurisdictional baseline deforestation rates if deforestation is declining over time



Source: Own illustration.

Figure 3 illustrates this for a simplified example of a jurisdiction where deforestation rates are declining. In this example, we assume that without carbon crediting projects deforestation in the jurisdiction would decrease linearly and would be halted by 2050 (black line). We further assume that the implementation of carbon crediting projects brings this decline forward by five years (green line). The baseline for the first baseline validity period from 2021 to 2026 (red line) is determined based on the average deforestation observed in the period 2011 to 2020 (red dotted line). Due to the decline in deforestation levels, the baseline is significantly higher than the true – but unknown – deforestation levels without the projects (black line). This also holds for subsequent baseline periods. Under a trend of declining deforestation rates, the use of historical data could thus lead to a systematic overestimation of baseline emissions. By contrast, if deforestation increases over time, the baseline could be systematically underestimated, as the increase in jurisdictional emissions would also only be captured with a time delay.

The implications do not only depend on whether and how strongly deforestation levels increase or decrease over time but also on the impact of carbon crediting projects on deforestation levels. As highlighted above, the baseline could also be systematically underestimated as the historical data includes the impacts from carbon crediting projects. Without carbon crediting, the historical deforestation levels would be higher. Figure 3 shows the combined effect from overestimation of the baseline if deforestation levels were to decline and potential underestimation of the baseline due the impact of carbon crediting projects on deforestation in the historical reference period.

The impact of this effect can be large. In the example of the figure, the baseline would be overestimated by 43% over the entire period (i.e., the red line is on average 43% higher than the black line over the period 2021 to 2056 when the last baseline validity period ends). The impact on overestimation of emission reductions from carbon crediting projects depends on how the projects within the jurisdiction reduce deforestation. In the example of the figure, it could range between 43% and 252% (assuming no error from the risk allocation model). If the reduction in deforestation would be only achieved through projects that manage to reduce deforestation to zero over the entire period, then the overestimation of emission reductions would be equal to the overestimation of the baseline and thus amount to 43%. The largest possible overestimation would occur if projects would cover the entire jurisdictional area. In this case, the credited emission reductions (the area between the red line and the green line) would be 252% larger than the actual emission reductions (the area between the black line and the green line). The impact on overestimation of credited emission reductions thus depends on how the reduction in deforestation is achieved by projects.

A variation of these underlying parameters shows that the impacts could strongly vary. For example:

- If deforestation would be halted by 2040 without carbon crediting projects and if carbon crediting projects have only a smaller impact and bring the halting of deforestation forward by two years, to 2038, then baseline emissions would be overestimated by 86% on average over the period. The emission reductions could then be overestimated between 86% and 820%, depending on how the projects are implemented.
- If deforestation would only be halted by 2070 without carbon crediting projects and if carbon crediting projects have a major impact and bring this forward to 2050, then the baseline would be underestimated by 6%. In this case, the effect of underestimating the baseline due to impact of carbon crediting projects on the historical data in the reference period prevails over the effect of underestimation of the baseline due to declining trends in deforestation.

This analysis shows that two parameters are critical to assess the risk of potential overestimation of the jurisdictional baseline rate: (a) whether deforestation will increase or decrease over a longer period and how strong any such trend is, and (b) how large the impact of carbon crediting projects on deforestation levels is. Both parameters are associated with considerable uncertainty.

The available data suggests that deforestation is increasing in some jurisdictions and decreasing in others. The jurisdictional baseline under VM0048 would be conservative if deforestation would continue to increase and not be halted at some point in time. However, at some point in the future, deforestation may always decline and be halted – at the latest when all forests are lost. The literature also suggests that countries undergo different forest transition phases that ultimately halt deforestation (see, for example, Hosonuma et al. 2012).

Another consideration is how policies affecting deforestation rates may evolve over time. Many governments and non-governmental actors have committed to slowing and ultimately halting deforestation, such as in the New York Forest Declaration and the Glasgow Leaders' Declaration on Forest and Land Use. Many countries have also pledged ambitious NDC targets and long-term low emission development strategies (LEDS). This could support the implementation of national polices that slow deforestation. On the other hand, developing countries are lacking finance to implement such policies and current efforts would need to be considerably enhanced to reach the goal of halting and reversing deforestation by 2030. In addition, other drivers, such as prices for agricultural commodities, increased use of biomass and land competition could increase pressure on forests.

Over a longer horizon, with the enhanced policies to slow and halt deforestation, we consider it plausible that deforestation could, in aggregate across jurisdictions, slow over time and ultimately be halted at some point in the future, though this unlikely to be achieved by 2030. If this assumption holds, then the approach in VM0048 could, in aggregate across jurisdictions, lead to a systematic bias towards overestimating baseline emissions.

To address this matter, the methodology could, for example, assume a jurisdictional baseline that uses historical data as a starting point but declines over time and reaches zero deforestation at some point in the future, choosing a conservative trajectory in the light of the uncertainty. Another approach could be alignment of the baseline with the NDC and LEDS of the host country, and the long-term goals of the Paris Agreement, as required under the carbon crediting mechanism established under Article 6.4 of the Paris Agreement.

Potential overestimation of baseline levels due to continued crediting even if no forest would be available anymore

The methodology does not consider whether forest land would in the baseline scenario still be available for deforestation. If deforestation stops in the baseline scenario at a future point because all forests have been deforested, the methodology still allows claiming carbon credits after that point in time although no such emission reductions would be physically possible. For example, if baseline deforestation in a jurisdiction would be constant in the period from 2010 to 2050 and all forest area would have been deforested by 2050, then the methodology would still allow projects to claim emission reductions thereafter, for up to 12 years. In the baseline validity period from 2051 to 2056, the baseline would be based on the constant deforestation rate observed in the period from 2041 to 2050. Even in the next baseline validity period from 2057 to 2063, project developers could still claim some emission reductions, because the average deforestation rate in the period 2047 to 2056 would be used, which still includes four years in which deforestation occurred (2047 to 2050). The methodology thus allows assuming aggregated total baseline deforestation levels to exceed the forest land available for deforestation. In practice, however, this issue is unlikely to materialize. In most countries, there are still large amounts of forests. And if efforts to reduce and stop deforestation are successful, then this issue may also not materialize.

Overall assessment

In summary, in our assessment, assuming average historical deforestation rates as the jurisdictional baseline scenario could lead to significant overestimation. Most importantly, there is large uncertainty in short-term changes in jurisdictional deforestation rates at the level of individual jurisdictions. This could result to large over- or underestimation of the jurisdictional baseline. This could result in more carbon credits coming from jurisdictions with overestimated baselines, thereby undermining the integrity of the portfolio of projects. Second, while assuming average historical deforestation rates to continue in the future is a well-established practice in jurisdictional approaches, this may not be a likely scenario over a longer time horizon. And third, the impact of carbon crediting project on deforestation levels in the historical reference period could lead to some underestimation. However, this effect could, under a broad range of circumstances, be much smaller than the effect of potentially declining trends in deforestation.

Overestimation of baseline emissions, or large uncertainty in baselines, could also have a large effect on overestimation of emission reductions, as projects may not be able to entirely address deforestation drivers and may only moderately reduce deforestation. Next to addressing uncertainty in baselines, it is therefore important that projects are effective and strongly reduce deforestation levels. This would alleviate the implications of baseline uncertainty.

We assess that these issues affect a **high** fraction of projects. The degree of overestimation of total credited emission reductions is **unknown**. The variability among projects in the degree of overestimation is also assessed to be **high**.

UE8 **Discounting for uncertainty in historical deforestation data.** The methodology requires estimating the uncertainty in the estimated total area of unplanned deforestation in the jurisdiction in the historical reference period. A discount to the estimate is applied if the uncertainty is above 10% and below 20%. This could potentially lead to underestimation of total credited emission reductions. It is, however, unclear for how many jurisdictions the uncertainty will be determined to be within the range where a discount applies. Therefore, the fraction of projects affected is **unknown**. Where this issue materializes (i.e., the uncertainty is larger than 10% and an uncertainty deduction is applied), the applied discount is between 10% and 20%, and the degree of underestimation thus **medium**. The variability in the degree of underestimation among projects is **unknown**.

OE4 **Exclusion of areas with planned deforestation and natural disturbances:** To improve accuracy of the activity data estimates, areas of planned deforestation and natural disturbance can be excluded from sampling. Excluding such areas is a requirement for areas above 1000 ha and optional for smaller areas. The methodology does not clarify whether the threshold is applied to one year or over the ten-year historical reference period. In principle, exclusion of these areas is appropriate; including them would lead to inflated estimates of unplanned deforestation levels in the jurisdiction. However, the inclusion of areas below the 1000 ha threshold in the calculation would lead to overestimation of the jurisdictional unplanned deforestation levels and thus overestimation of the baseline. This risk is assessed to apply to a **high** fraction of projects, as some degree of inclusion of areas with planned deforestation or natural disturbances is likely to occur in most jurisdictions.

Where this issue materializes, we estimate that the degree of overestimation of total credited emission reductions is however rather **low**. The variability among projects in the degree of overestimation is **unknown**.

With regard to the establishment of the risk map, we identify the following elements of possible overestimation, underestimation or uncertainty:

Un3 **Uncertainty in the forest cover benchmark map:** Accuracy of the forest cover benchmark map is assessed against the sample-based observations made to determine the activity data. Two measures to enhance accuracy are used. The first looks at how much of the area mapped to a specific class corresponds to the sampled land cover. The second looks at how much of the area with a specific land cover is assigned the correct corresponding class. The methodology requires assessing the accuracy of the estimate of deforested area (change of forest cover between the start and the end date of the historical reference period) and the accuracy of the estimate of forest area at the end of the historical reference period. This is done by estimating for each class (forest/non-forest) the proportion of pixels correctly assigned to the actual land cover or land use on the ground (user's accuracy) and by estimating the proportion of areas on the ground that are assigned to the correct corresponding class on the map (producer's accuracy). For the deforestation estimate, 70% or more of the area must be correctly assigned, for forest at the end of the historical reference period, 90% or more of the area must be correctly assigned. Lower thresholds apply for forests with a canopy cover of 50% or below (60% for deforestation and 80% for forest cover and the end of the historical reference period). These accuracy provisions means that total deforestation in the reference period can be over- or underestimated to a large degree. The issue applies to **all** projects and is estimated introduces a **high** degree of uncertainty to the estimation of total credited emission reductions. The variability in the uncertainty among projects is **unknown**.

Un4 **Uncertainty in the models used to establish the risk map:** Allocating the jurisdictional average annual rate of unplanned deforestation to specific areas 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. While distance to forest edge may be more easily incorporated into models, other important factors driving deforestation, such as the current land-use in non-forest land areas, distance to roads and slope can affect where deforestation will take place. Such data is however more difficult to obtain and incorporate into models. The methodology takes this into account and aims to reduce uncertainty but does not account for the model uncertainty in preparing the risk map). The benchmark model will only include distance to forest edge as a factor. The two alternative models that must be considered may also consider other factors. The model with the lowest median absolute error in the relevant historical period is used. This reduces uncertainty to some degree. However, the methodology does not pursue a conservative approach to address uncertainty (e.g., for example by comparing the results for each pixel from different models and choosing the most conservative outcome for each pixel or by adjusting all pixels by a factor to account for model uncertainty). This issue applies to **all** projects. The degree of uncertainty and the variability among projects is **unknown**.

Un5 **Potential overestimation of deforestation risk on the edge of natural disturbance:** Sampling of historical deforestation includes a step where areas of natural disturbances larger than 1000 ha and commercial plantations and deforestation by large scale infrastructure are excluded from the sampling frame. The same exclusions apply to the forest cover benchmark map. VMD0055 states that this is approach is pursued to ensure "that these forest clearings are not used to inform risk modelling of unplanned deforestation". In VT0007 all areas that are not forested at the beginning of the historical reference period are treated as stable non-forest and used to calculate the distance from forest edge. From this, we understand that areas affected by natural disturbances and classified as non-forest will be considered as a forest edge for the purpose of risk mapping. Areas close to this edge will be assigned the corresponding risk class. If deforestation in this area occurred due to natural disturbances and human drivers are largely absent, the assigned risk around these areas will be overestimated. In remote areas, this could even overestimate the deforestation risk in these land pixels by 100%. From the description in VT0007, it is further not clear how the risk close to permanent water bodies is treated. If they were treated as forest edge, the same risk of overestimation would apply. The issue is most relevant for the benchmark risk map and may be addressed in alternative risk maps, where additional factors are considered. The number of projects affected by this issue is **unknown**. Where the issue materializes it introduces a **low** degree of uncertainty. The variability in the uncertainty among projects is **unknown**.

OE5 **Possibility of gaming baseline validity periods:** The baseline deforestation rates provided by Verra are valid for six years. Verra will determine the start and end date of a baseline validity period and provide an updated baseline for the following period. A project may start at any time within a baseline validity period. For example, the first baseline validity period could start on 1 January 2025 and may end on 31 December 2030. The subsequent baseline validity period with updated baseline data would then start on 1 January 2031 and end on 31 December 2036. Projects that start within the first baseline validity period (e.g., in 2028) can choose between transitioning to the updated baseline right away or applying the 2025-2030 baseline for a maximum of two years and then transition to the next baseline. In the former case, this project could use a baseline for a period of eight instead of six years. If jurisdictional baselines and risk maps are publicly available or projects are informed about their updated baseline upon request, project proponents would have the possibility to choose the baseline that is higher. Even if they could not formally inquire about the new baseline data applicable to their project, it seems likely that they could derive from other information (e.g., other projects, public data on deforestation rates in the region) whether the updated jurisdictional baseline is higher or lower than the previous baseline. If all projects choose the higher baseline among two plausible options, this will in aggregate across projects lead to overestimation of total credited emission reductions. It is unclear to how many projects this risk will apply. If all projects transitioning from the existing methodologies must apply the VM0048 methodology as of 1 January 2025 and thus use the updated baseline as of 1 January 2031, this risk would not apply to currently registered projects but only to new projects. This issue is only relevant for the transition from the first baseline validity period to the second. We therefore assume here that this issue only applies to a **low** fraction of projects, though their share may increase over time. Where this issue materializes, we estimate that the degree of overestimation of total credited emission reductions could be **low to medium** (up to 30%), given that historical deforestation levels can vary considerably. The variability in the degree of overestimation among projects is assessed to be **high**, given that the degree of changes in updating baselines could vary considerably among jurisdictions.

OE6 **The allocated baseline may be higher than a government baseline:** Where governments establish a jurisdictional deforestation baseline and that baseline is lower than the deforestation baseline determined by Verra, project developers are not required to use the lower governmental baseline, unless this is mandated by regulation. It is plausible that most project developers would in such instances choose the higher baseline provided by Verra. This provision only contributes to overestimation, or prevents more conservative estimates, where the baseline provided by Verra is overestimated. The fraction of projects affected by this issue, the degree of overestimation and the variability in the degree of overestimation among projects are all considered to be **unknown**.

Potential elements of overestimation, underestimation or uncertainty with regard to the determine of baseline emission factors (carbon stocks lost per hectare of deforested land) are discussed further below in the section “Quantification of carbon stocks in the project and the baseline scenario”.

Determination of the geographic boundaries of the project

The methodology VM0048 has provisions to clearly define and delineate the project area, including through maps and geographic coordinates. The project area may encompass more than one discrete area of land. Moreover, each discrete forest area "must be continuous without arbitrary exclusions of forests in the same geography (e.g., without excluding forests next to villages around which deforestation is likely to occur)".

The project boundary section of module VMD0055 further specifies that geographical boundary of the project area remains fixed for the duration of the project crediting period, regardless of any land cover change after the start of the project. However, it provides for an exception where a "project activity instance (or equivalent) leaves the project (e.g., a landowner decides to leave a project) before the end of the crediting period". In this case, the project "must conservatively assume a loss of all previously verified emission reductions associated with the excluded area", exclude the respective area, and recalculate baseline emission respectively.

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

OE7 **Selection of favorable project areas:** The allocation of baseline deforestation data to projects by Verra considerably reduces the flexibility by project developers compared to the previous methodologies by Verra. A key question is whether there is a risk that project developers could select those areas in which the risk map overestimates deforestation risk. This risk may arise from two factors: first, the preparation of the risk map is associated with considerable uncertainties (see Un4 to Un6), making it likely that deforestation risk is overestimated in some areas and underestimated in other areas. Second, the risk map can only incorporate a limited number of factors. Projects developers may have access to local knowledge that cannot be considered in building the risk maps. For example, project developers may be aware of plans to build roads and select regions that are further away from these planned roads. If these plans were not considered in developing the risk map, the deforestation risk may be under-allocated in the areas where the roads are planned and accordingly overallocated in all other areas of the jurisdiction. Another example could be that a forest has a value to local communities due to reasons that cannot be picked up by risk modes (e.g., generation of forest-related products and services or a certain area being sanctuary to local communities).

This risk also depends on the degree to which project developers can shape the area. The methodology states that “the forested project area (within each discrete area of project activity) must be continuous without arbitrary exclusions of forests in the same geography (e.g., without excluding forests next to villages around which deforestation is likely to occur)”. While the intent of the methodology is that areas with higher deforestation risk are not systematically excluded, it is unclear how well this can be prevented in practice, given that the methodology allows that the project area may consist of several discrete land areas that may not be connected. This provides some flexibility to project developers to construct the project areas around areas with overestimated deforestation risks. A further challenge is the information asymmetry between project developers and third-party auditors or the carbon crediting program in assessing whether "arbitrary exclusions" have been made.

At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. Whether and to what extent this risk materializes depends on several factors. One factor is the level of information that Verra makes available in the risk maps. According to information provided by Verra to CCQI, the risk maps will be made publicly available, although it is not clear at which spatial resolution. The risk also depends on the fit and uncertainty of the models used to prepare the risk map. If the fit is good and the uncertainty is low, the risk that project developers identify areas where modelled deforestation rates are likely overestimated may be lower. Moreover, this risk applies only to new projects developed under the methodology but not to projects that were originally registered under the previous methodologies by Verra (except if the project area of existing projects could be changed when transitioning to the VM0048 methodology). We here assume that existing projects cannot alter their project areas when transitioning to VM0048 and that the risk therefore only applies to new projects. This means that in the next years the fraction of projects affected by this risk is **low** but could substantially increase in the future. We estimate that where this issue materializes the degree of overestimation of total credited emission reductions is likely to be **low to medium** (up to 30%). The variability in the degree of overestimation among projects is likely to be **high**.

OE8 **Ex-post determination of the project area:** The VCS programs allows projects to retroactively claim credits for time periods before the project registration is finalized. Avoided deforestation projects must complete validation only five years after the project start (VCS Standard, Version 4.6, paragraph 3.8.4). At the same time, the exact shape of the project area only needs to be finalized when starting the validation of the project. This enables project developers to ex-post adjust the project area at validation stage, for example by including areas where actual deforestation observed in the first years of the project was lower than predicted in the risk map and excluding areas where observed deforestation was higher than predicted in the risk map. This would lead to a systematic overestimation of the project's emission reduction impact. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The number of projects affected is therefore **unknown**. Where this issue materializes, we estimate that the risk of overestimation is **medium**. The variability in the degree of overestimation is likely to be **high**. Note that Verra informed CCQI that it is planning to change its project start date rules. A consultation on this matter is planned to go out in summer 2024.

OE9 **Ex-post exclusion of project areas:** The methodology assumes that the provisions for ex-post exclusion of project areas are conservative, given that all previous emission reductions are assumed to be reversed in such cases. This may be conservative where the area that leaves the project is not further deforested thereafter. However, it may also be plausible that a landowner wishes to leave the project because of its intent to engage in larger deforestation. If an area is excluded where little or no deforestation has occurred in the past, and the area is more strongly deforested following the exclusion, then the exclusion would lead to an overestimation of the projects impact. In our assessment, this latter scenario is more plausible. Another scenario of how this provision could lead to overestimation is if project proponents exclude areas with currently low deforestation, but where they know that an increase is very likely, for example because they know that in some areas their project interventions are failing or that new roads will be constructed. Under both scenarios, overestimation would occur if the area is excluded from monitoring and if the impact of future deforestation in the area is larger than the previously calculated emission reductions for that area. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The fraction of projects affected by this issue and the degree of overestimation where this issue materializes are **unknown**. The variability in the degree of overestimation among projects is likely to be **high**.

OE10 **Reshaping of project area at renewal of the crediting period:** The VCS module VMD0055 requires that the project area is unchanged during a crediting period (with the exception of the provisions for exclusion discussed above). There are no provisions in the methodology that prevent project developers from reshaping the project area at the renewal of the crediting period. Due to the risks highlighted above with regard to selection of favorable project areas, project developers could reshape the area with the view to excluding areas where deforestation risk may be underestimated in the risk maps provided by Verra and including areas where deforestation risk may be overestimated. In aggregate across projects, this could lead to overestimation of total credited emission reductions. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The fraction of projects affected by this issue and the degree of overestimation where this issue materializes are **unknown**. The variability in the degree of overestimation among projects is likely to be **high**.

Quantification of carbon stocks in the project and the baseline scenario and determination of deforestation rates under the project

Under the VM0048 methodology, the calculation of emission reductions is based on the difference in deforestation rates between the baseline and the project (referred to as activity data) and the difference in carbon stocks per hectare of land between forest area and post-deforestation land (referred to as the emission factor). While the baseline deforestation rates (baseline activity data) are provided by Verra to projects, the deforestation in the project area observed after the implementation of the project (project activity data) and the carbon stocks per hectare of land (emission factors) are determined by each project. This section focuses on the determination of this project-specific data.

In the four older VCS methodologies (VM0006, VM0007, VM0009 and VM0015), carbon stocks are mainly determined through sampling or by using existing values from previous inventories. In VM0048, carbon stocks are determined in the project area through sampling. All methodologies encourage to stratify the relevant forest area to reduce uncertainty of carbon stock estimates.

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

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

OE11 **Overestimation of emission factors due to limited consideration of degradation:** Next to deforestation, it is possible that significant levels of forest degradation occur in the project area. This holds in particular where forest is defined based on a relatively low canopy cover, as is usually the case with national forest definitions that are allowed to be used under the methodology. In this case, a significant amount of forest carbon stocks may be lost without qualifying as deforestation.

The methodology does not provide guidance on how forest, deforestation and forest degradation should be defined in the context of the jurisdiction and specific project types. Guidance on the choice of these definitions would be necessary for different forest types, biomes or ecosystems, taking into account the specific features of the ecosystems and landscape units and the monitoring methods. Verra informed CCQI that for each jurisdiction these definitions will be determined by Verra in consultation with the government, local stakeholders and Verra’s data providers. The relevant definitions are communicated to project proponents with their data allocation.

Projects are required to estimate the emission factor (i.e., the difference in carbon stocks per hectare in forest strata and in post-deforestation land-use) once at the start of the six-year baseline validity period. The module VMD0055 requires the consideration of degradation under defined conditions, namely in the presence of new roads or in areas where the canopy cover decreases by 50% or more (section 5.3.3.2).

This implies that degradation occurring during the six-year period would in most cases not be captured in the estimate of the emission factors. As it is plausible that forests in the project area degrade over time, in particular where forest definitions with a low canopy cover are used, emission factors estimated ex-ante may not be representative for the six-year period, but rather reflect the level of degradation at the start of the period and are thus overestimated. 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. This may lead to an overestimation of total credited emission reductions. In our assessment, this is likely to affect a **high** fraction of projects. The degree of potential overestimation is **unknown** as it is difficult to predict how much degradation would occur within a six-year period. The variability in the degree of overestimation among projects is likely to be **high**.

Un6 **Uncertainty due to lack of accounting for forest degradation:** Next to the issue of overestimating emission factors (OE11), not accounting for degradation introduces uncertainty in the overall estimate of emission reductions. The implementation of the project could not only influence deforestation levels but also the degree of forest degradation. This could have different effects: Some projects may reduce both deforestation and forest degradation. In this case, the reduction in degradation would not be accounted for, as the project only accounts for changes in deforestation. This would lead to an underestimation of total credited emission reductions. Some projects may take actions that lead to deforestation but result in an increase in degradation. This could, for example, occur where the measures implemented through the project would shift drivers of deforestation or forest degradation from areas that are at the edge of deforestation to areas where the forest is still more intact. This would lead to an overestimation of total credited emission reductions. Not accounting for forest degradation could thus lead to under- or overestimation, and thus introduces uncertainty in the estimate of overall emission reductions. This issue applies to **all** projects under the currently available version of the methodology and modules. The level of uncertainty and the variability among projects are **unknown**.

Un7 **No minimum mapping unit:** The methodology does not refer to a minimum mapping unit for remote sensing classification and therefore implicitly allows large minimum mapping units and high resolution. This introduces further uncertainty, in particular in the context of ‘mosaic’ landscapes. This applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

UE9 **Application of a discount for uncertainty in the carbon stock change estimates:** A discount factor to account for uncertainty is applied. The factor is determined based on the uncertainty of the weighted average carbon stock change estimated during the historical reference period. The weighted averages are calculated according to the area of each forest stratum and for each carbon pool. If the uncertainty is below or equal 10%, the discount factor is 0. For uncertainty above 10% and below 100% the discount factor is applied for all pools together, although soil carbon and wood products pools are kept separately. Only if uncertainty is above 100%, additional sampling is required. The application of the discount factor results in an underestimation of total credited emission reductions. This uncertainty estimation in VM0048 is an improvement compared with previous methodologies.

Where carbon stock estimates are derived from sampling, the uncertainty estimates are also derived from the sampling. Where literature sources (including IPCC guidance) are used for carbon stock estimates, the uncertainty associated with these data must also be estimated. Data ranges may be used as proxies of confidence intervals. This provision lacks clarity for how project developers should estimate uncertainties from data ranges. Data ranges provided in IPCC guidelines are neither confidence intervals nor uncertainties. They indicate the range in which the values may be found, but uncertainties can be much larger. Thus, while pragmatic, the approach is scientifically incorrect. Moreover, some sources of uncertainty, such as uncertainties from allometric equations and root-to-shoot ratios, are not considered. Thus, the uncertainty estimation may also be incomplete, depending on the specific approach and parameters chosen. This will likely reduce the degree of conservativeness in applying the discount factors.

This issue applies to **all** projects since uncertainty is inherent to estimations of carbon stock changes. We expect that project proponents have an incentive to keep uncertainty low, but high levels of uncertainty are also allowed. As the methodology is new, it could not yet be checked how this uncertainty estimation is applied in practice and to what extent it results in resampling to reduce high uncertainties. We estimate that the degree of underestimation due to uncertainty discounts is likely to be **low** (up to 10%) because additional sampling in cases where uncertainty is above 100% is likely to be conducted and because of the limitations how overall uncertainty is derived, as described above. The variability in the degree of underestimation among projects is **unknown**.

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

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 observed with the methodologies VM0006, VM0009, VM0007 and VM0015. Haya et al. (2023) analysed a sample of avoided deforestation projects using these methodologies and found that the allometric equations chosen by the project developers resulted in aboveground 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 higher 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**.

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

The module VMD0001 requires to choose root-to-shoot ratios with the following order of 'priority': "detailed data collected using common practices for root sampling in the area; globally forest type-specific or eco-region-specific (e.g., IPCC GPG-LULUCF); or root to shoot ratios for tropical and subtropical forests modified from Table 4.4. in IPCC GL AFOLU". The guidance further specifies that mean values from relevant sources are considered to be 'conservative'; however, IPCC and literature values commonly provide the best estimate and are not conservative (i.e., they do not err towards underestimating these values).

As with other parameters in this assessment, the flexibility to choose from different sources, including picking between the 2006 IPCC Guidelines and the outdated IPCC GPG, with limited guidance on prioritization of data sources and no requirement to use conservative values, poses the risk that project developers pick favorable root-to-shoot ratios that overestimate belowground biomass.

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

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

OE14 **Overestimation of the carbon fraction in biomass:** The carbon fraction in biomass is the percentage of total dry aboveground biomass that is carbon and is applied to the estimates of aboveground biomass derived from the allometric equations. For tropical trees, Martin et al. (2018) derived a best estimate of 0.456 based on a global synthesis of over 2,000 wood carbon concentration measurements. For tropical woodland trees Ryan et al. (2011) determined 0.47 as the most appropriate value. This value is also used as a global default value in the 2006 IPCC Guidelines (Volume 4, Chapter 4, Table 4.3). The module VMD0001 states that values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3) shall be used if available, otherwise a default value of 0.47 can be used. 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**.

UE10 **Application of a discount for uncertainty in the project deforestation rates:** A discount factor to account for sampling uncertainty in determining project deforestation rates is applied where the sampling uncertainty is larger than 10%. The application of the discount factor results in an underestimation of total credited emission reductions. This uncertainty estimation in VM0048 is an improvement compared with previous methodologies. The fraction of projects affects is estimated to be **low**, as we assume that most projects are likely to pursue measures to reduce the sampling uncertainty below 10%. Where a deduction is applied, the degree of underestimation is likely to be **low** (up to 10%). The variability in the degree of overestimation among projects is **unknown**.

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 VM0048.

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 VM0048

The VM0048 methodology estimates leakage emissions by considering four types of leakage:

1. **Activity shifting by geographically constrained agents:** This refers to agents that may displace deforestation drivers (e.g., timber harvesting) to surrounding areas the project, potentially resulting in increased deforestation in these areas. Changes in deforestation must be monitored within an area where unplanned deforestation by geographically constrained agents may be displaced to. The area is referred to as ‘Unplanned Deforestation Leakage Belt’ (referred to as UDef LB).

2. **Activity shifting by geographically mobile agents:** This refers to migration of agents to the project area which may drive deforestation in the baseline scenario. Due to the implementation of the project, these agents may shift to other areas, potentially causing land-use changes in these areas.

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. It includes emission from any carbon stock losses and non-CO_2 emissions from biomass burning or fertilizer use. These emissions are determined following the provisions in VMD0055 unless deemed de minimis.

The significance of leakage emissions is determined using Appendix 1 of the methodology (see description in the project boundary section above and OE1).

Emissions from activity shifting due to the displacement of geographically constrained activities are calculated based on the difference in carbon stocks between the baseline scenario and the monitoring period within the Unplanned Deforestation Leakage Belt (UDef LB). Additionally, significant non-CO_2 GHG emissions from fossil fuels or burning of biomass resulting from an increase in deforestation are considered. These emissions are assumed to have the same intensity (emissions per unit of land) as in the project area in the baseline period.

Emissions from activity shifting by geographically mobile agents are determined based on several parameters. A survey is conducted to determine the proportion of households in the project area that both (a) recently migrated into the project area and (b) engaged in land-use activities identified as a deforestation driver. This is referred to as the 'Proportion of Migrated Land Cover Transition Agents' (PROMIG). The methodology assumes that the land conversion due to activity shifting outside the project area corresponds to the product of this proportion and the land area prevented from deforestation. In other words, if 3% of the population has recently migrated to the project area and engaged in activities leading to deforestation and the project prevents 100 ha from being deforested, it is assumed that 3 ha of land would be deforested outside the project area. Moreover, Verra determines a total maximum area available for deforestation outside the project area. If the area of land conversion outside the project area due to activity shifting by geographically mobile agents is larger than the available area, then no further increase in deforestation outside the project activity is assumed.

The available area for activity shifting outside the project area and the emission factor (the emission per hectare from land conversion outside the project area) are provided by Verra as part of the baseline allocation report (which determines the project's avoided deforestation baseline data). The available area for activity shifting is determined by spatially delineating areas of forest and non-forest land available for leakage by considering factors like suitability for agriculture, physical accessibility, and lack of legal protection. Jurisdictional maps of each of these three factors are combined into a single map that is considered as area of "available land".

The emission factor is calculated based on the average amount of carbon released per hectare of forest converted to agriculture in the "available" land areas and level of carbon stored above and below ground. Carbon stratification maps are used to estimate the extent of each jurisdictional carbon stratum that falls under the available category. The map, sourced from peer-reviewed forest carbon stock maps, are overlaid on maps of "available" arable lands to calculate the average stock.

Emissions from market leakage are determined using the module 'Estimation of emissions from market effects' (LK-ME). Market leakage only needs to be considered when the baseline scenario involves wood harvesting for commercial markets (timber, fuel wood, or charcoal).

For quantifying market leakage through decreased timber harvest, the leakage deduction depends on where harvesting is likely to be displaced to. If harvesting moves to a forest with a lower proportion of merchantable biomass compared to the project area, then more trees need to be cut, resulting in higher emissions. However, if the displaced area has a higher proportion of merchantable species, fewer trees will need to be harvested, leading to lower emissions. The leakage deduction thus depends on a comparison in the proportion of total biomass that is merchantable in the project area and in other areas (see Table 2). The module does not specify which other areas should be used for comparison. Projects that demonstrate that market leakage occurs only outside the country can set leakage to zero. If leakage management activities are carried out to minimize displacement of land use activities or if the leakage management area produces usable biomass, the market leakage deductions are further adjusted by a 'leakage management adjustment factor'.

Table 2: Market leakage deduction factors

Deduction Factors for LFME	
PMLFT is equal (± 15%) to PMP	LFME = 0.4
PMLFT is > 15% less than PMP	LFME = 0.7
PMLFT is > 15% greater than PMP	LFME = 0.2

Note: PML_{FT} corresponds to the mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type. PMP corresponds to the merchantable biomass as a proportion of total aboveground tree biomass for the respective stratum within the project boundary.

Leakage effects from reduced fuelwood or charcoal production are determined in a similar way. In this case, a survey of households and assumptions on population growth are used to predict fuelwood and charcoal use in the baseline. A leakage factor of 0.4 is applied.

The methodology also includes a procedure to determine leakage emissions from any peatland drainage that may occur on lands which may be converted due to market leakage. Relevant areas are identified through remote sensing. The leakage emission factor is estimated based on of carbon contained in the peat.

Emissions from leakage prevention measures must be accounted for and included as emissions caused by project implementation if they result in substantial increases in emissions from carbon stock changes, biomass burning, and/or increased fertilizer usage. The project description should include detailed planned leakage mitigation measures, specify their location (demarcate leakage management zone), and identify areas where such measures affect carbon stocks. In these specific zones, the net carbon stock changes in above- and below-ground tree biomass expected to occur due to the implementation of planned leakage mitigation must be estimated using conservation growth projects. If the sum of carbon stock changes within the leakage management zones over the monitoring period is expected to be greater than zero, then the total increase can be ignored in the estimation of net GHG emission reduction. However, if the sum of carbon stocks is negative, the significance of GHG emissions must be tested using Appendix 1 of VM00048. The significance test must also be applied to biomass burning and fertilizer usage.

When emissions are determined to be significant, they must be monitored. However, the methodology specifically excludes any increase in emissions due to the combustion of fossil fuels from leakage prevention activities. The methodology states that CDM TOOL07 must be employed to estimate any significant increases in fertilizer use due to leakage prevention.

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

Un8 **Uncertainty in determining leakage emissions from geographically constraint agents:** The calculation of this leakage source involves many assumptions that are subject to large uncertainties. The possibly largest source of uncertainty is the estimate of baseline deforestation rates in the leakage belt. This data is determined and provided by Verra, following the same methodological approach as for the project area. As highlighted further above, there is large uncertainty in baseline deforestation rates that is not accounted for. This creates particularly large uncertainty for the quantification of leakage emissions from activity shifting of geographically constraint agents because the actual (unknown) changes in deforestation rates due to leakage from activity shifting are likely to be small in comparison to the baseline uncertainty, creating a signal-to-noise issue. Depending on the accuracy of the baseline deforestation estimates, leakage emissions could be very significantly over- or underestimated. This issue affects **all** projects. The impact on the overall uncertainty of emission reductions is, however, more limited because leakage from activity shifting is usually relatively small compared to overall emission reductions (see discussion of literature above). We estimate that this issue introduces a **low to medium** degree of uncertainty to the estimation of total credited emission reductions. The variability in the uncertainty among projects is estimated to be **high**.

Un9 **Uncertainty in determining leakage emissions from activity shifting by geographically mobile agents:** The calculation of this leakage source also involves many assumptions that are subject to large uncertainties. Overall, in our assessment the resulting calculation may not well reflect the likely actual leakage rates, for various reasons. It is not clear why the proportion of land that is subject to conversion is based on the proportion of migration that is observed under the project (where deforestation is halted and migration into the project area may be strongly reduced), rather than the migration expected to occur in the baseline scenario. This assumption may contribute to underestimating leakage effects. The methodology also seems to assume lands that are currently used for agriculture, such as grasslands, are available for conversion. However, conversion of lands used for cattle grazing to other agricultural use could cause a chain of other land management practices and conversions, ultimately leading to deforestation. This assumption may also contribute to underestimating leakage effects. We also note that this source of leakage may partially overlap with market leakage, depending on the type of deforestation agents. There is also considerable uncertainty in quantifying the emission factors from any land version as a result of activity shifting. This issue applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

OE15 **No accounting for market leakage due to agricultural activities.** The methodology requires market leakage deductions to be applied only when timber, fuelwood, or charcoal production are identified as deforestation drivers. 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.

OE16 **Use of historical records and flexibility in determining baseline timber, charcoal and fuelwood production in market leakage calculations:** The quantification of market leakage strongly hinges on predictions on how much timber, charcoal and fuelwood would be produced in the baseline. The methodology allows project developers to use "timber harvest records and/or estimates derived from field measurements and/or assessments with aerial photography or satellite imagery". The methodology thus allows using historical records to predict the future production of timber in the baseline scenario. For many avoided deforestation projects, however, historical deforestation rates prior to the implementation of the project are likely to be lower than deforestation rates assumed to occur in the baseline scenario after project start. This is because the methodology requires that the project area must "include only land qualifying as forest for a minimum of 10 years before the project start date" (section 5.1 of VM0048) and as the deforestation front is, in the baseline scenario, likely to encroach into the project area over time, increasing deforestation levels. Historical records of timber generation may thus underestimate future levels that would occur in the baseline scenario. Similar considerations hold for the determination of baseline quantities of fuelwood and charcoal. Here surveys among households and projections about population growth may be used. However, this data may not align with a baseline scenario where deforestation could be driven by production of fuelwood and charcoal for other neighboring regions (and just for subsistence within the project area).

The assumptions in the methodology used for determining baseline deforestation (derived by Verra using jurisdictional activity data and risk maps) are thus inconsistent with the assumptions used for quantifying market leakage (derived by project developers based on historical records or surveys assuming only subsistence use of fuelwood or charcoal). Moreover, the methodology provides considerable flexibility to project developers in quantifying such levels. They may use several different data sources and the exact geographical area or period over which historical records are used is not defined. Moreover, satellite imagery may provide information on historical deforestation rates but does not provide information on the purposes for which wood may be used and over which distances it is transported. The approach thus provides considerably leeway to project developers to pick approaches that underestimate the baseline volume of timber, charcoal or fuelwood production for commercial purposes. This issue is likely to affect a **high** fraction of projects. Where this issue materializes, we estimate that is leads to a **low to medium** overestimation of total credited emission reductions (up to 30%). The variability in the degree of overestimation among projects is estimated to be **high**.

OE17 **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' (PML_{FT}). 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**.

Un10 **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**.

OE18 **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., timber products). Even if these commodities are used within national boundaries, they could impact the level of imports or exports and thereby lead to international leakage. This risk is likely to be lower for avoided unplanned deforestation as compared to avoided planned deforestation. 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**.

UE11 **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 zone 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 this assessment of the VCS Methodology VM0048. For each of the elements discussed above it summarizes the potential impact on the quantification of emission reductions or removals.

Table 3 Relevant elements of assessment and qualitative ratings

Element	Fraction of projects affected by this element[4]	Average degree of under- or overestimation where element materializes[5]	Variability among projects where element materializes[6]
Elements potentially overestimating emission reductions or removals			
OE1: Lack of clarity regarding which emissions sources and carbon pools must be considered	Unknown	Low	High
OE2: Determination of significance of emission sources allows project developers to choose among multiple methods	Unknown	Low	Unknown
OE3: Establishment of the jurisdictional baseline scenario	High	Unknown	High
OE4: Exclusion of areas with planned deforestation and natural disturbances	High	Low	Unknown
OE5: Possibility of gaming baseline validity periods	Low	Low to medium	High
OE6: The allocated baseline may be higher than a government baseline	Unknown	Unknown	Unknown
OE7: Selection of favourable project areas	Low	Low to medium	High
OE8: Ex-post determination of the project area	Unknown	Medium	High

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[4] 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.

[5] 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.

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

Element	Fraction of projects affected by this element[4]	Average degree of under- or overestimation where element materializes[5]	Variability among projects where element materializes[6]
OE9: Ex-post exclusion of project areas	Unknown	Unknown	High
OE10: Reshaping of project area at renewal of the crediting period	Unknown	Unknown	High
OE11: Overestimation of emission factors due to limited consideration of degradation	High	Unknown	High
OE12: Flexibility in choosing allometric equations	Unknown	Low to medium	High
OE13: Flexibility in determining belowground biomass	High	Low	High
OE14: Overestimation of the carbon fraction in biomass	High	Low	High
OE15: No accounting for market leakage due to agricultural activities	Unknown	Unknown	High
OE16: Use of historical records and flexibility in determining baseline timber, charcoal and fuelwood production in market leakage calculations	High	Low to Medium	High
OE17: Flexibility in choosing key parameters to determine market leakage	High	Low to medium	High
OE18: No accounting for international leakage	Unknown	Unknown	High
Elements potentially underestimating emission reductions or removals			
UE1: Soil carbon is identified as an optional source	Unknown	Low	Unknown
UE2: Litter is identified as an optional source	Unknown	Low	Unknown
UE3: Emissions of from biomass burning is identified as an optional source in the baseline	Unknown	Low	Unknown
UE4: Above ground non-tree biomass is optional to include in the project's forest carbon stocks	Unknown	Low	Unknown
UE5: Deadwood is an optional pool	Unknown	Low	Unknown

Element	Fraction of projects affected by this element[4]	Average degree of under- or overestimation where element materializes[5]	Variability among projects where element materializes[6]
UE6: Methodology does not consider emissions from livestock	Unknown	Low	Unknown
UE7: N_2O emissions from the application of fertilizer are optional unless fertilizer use increases due to the project	Unknown	Low	Unknown
UE8: Discounting for uncertainty in historical deforestation data	Unknown	Medium	Unknown
UE9: Application of a discount for uncertainty in the carbon stock change estimates	All	Low	Unknown
UE10: Application of a discount for uncertainty in the project deforestation rates	Low	Low	Unknown
UE11: No accounting of any negative leakage	Low	Low	High
Elements with unknown impact			
Un1: Lack of clarity of definitions	All	Unknown	Unknown
Un2: Methodology does not require CO_2 from the combustion of fossil fuels to be included	Unknown	Low	Unknown
Un3: Uncertainty in the forest cover benchmark map	All	High	Unknown
Un4: Uncertainty in the models used to establish the risk map	All	Unknown	Unknown
Un5: Potential overestimation of deforestation risk on the edge of natural disturbance	Unknown	Low	Unknown
Un6: Uncertainty due to lack of accounting for forest degradation	All	Unknown	Unknown
Un7: No minimum mapping unit	All	Unknown	Unknown
Un8: Uncertainty in determining leakage emissions from geographically constraint agents	All	Low to medium	High

Element	Fraction of projects affected by this element[4]	Average degree of under- or overestimation where element materializes[5]	Variability among projects where element materializes[6]
Un9: Uncertainty in determining leakage emissions from activity shifting by geographically mobile agents	All	Unknown	Unknown
Un10: 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, the new methodology VM0048 is a major improvement to the previous Verra methodologies but could still lead to significant overestimation of emission reductions. The most important improvement of VM0048 compared to the older VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, VM0015) is that baseline deforestation data is determined by Verra and allocated to projects. This eliminates the considerable flexibility that the older methodologies provided to project developers in establishing baseline deforestation rates. In this regard, VM0048 can be expected to considerably reduce the large overestimation of emission reductions that is likely to occur under the older methodologies. A further important improvement is that the establishment of a jurisdictional baseline allows aligning project baselines with jurisdictional targets or crediting approaches.

Despite these significant improvements, we identify several integrity risks that could potentially have a significant impact:

- **Estimation of the jurisdictional baseline scenario:** While the use of average historical deforestation rates to establish the baseline scenario is common practice in jurisdictional approaches, this approach does not account for the large uncertainty in the jurisdictional baseline scenario and for potentially declining deforestation trends in a longer-time horizon. It could lead to large overestimation or underestimation of baseline emissions in individual jurisdictions and thereby undermine the integrity across a portfolio of projects (OE3).
- **Accounting for baseline uncertainty:** The methodology accounts for uncertainty more comprehensively than the older Verra methodologies. Nevertheless, some sources of baseline uncertainty are not accounted for, such as short-term changes in jurisdictional deforestation levels (OE3) or the uncertainty in the model to allocate deforestation risk within the jurisdiction (Un5). Unaccounted baseline uncertainty poses the risk that the calculated emission reductions could only be partially attributable to the project intervention and could partially be an artefact of wrongly set baselines. This risk can only be addressed if all sources of uncertainty in establishing the baseline scenario are accounted for and if projects have a strong and lasting impact on deforestation.

- **Risk of adverse selection:** Large baseline uncertainties paired with information asymmetry might also lead to adverse selection. There could be a risk that project proponents select project areas for which baselines are overestimated as they may have knowledge about the area, such as road or mining expansion plans, that is not graspable by the models used by Verra to predict deforestation risk (OE7). The methodology also allows projects to retroactively register areas in which past deforestation has been lower than estimated by Verra (OE8), or to exclude certain project areas after registration (OE9 and OE10). The extent to which these issues will lead to an overestimation of emission reductions is difficult to judge as the methodology has not yet been applied by projects.

- **Leakage accounting:** We identify several overestimation risks in the approach to account for leakage emissions. Data used to calculate market leakage is inconsistent with the data used to estimate baseline deforestation rates and the use of project-specific historical records or other data to establish market leakage rates raises the same type of issues that led to overestimation in baselines in the older Verra methodologies (OE16). International leakage is not accounted for though it could be a source of leakage in some contexts (OE18).

- **Quantification of carbon stocks:** We identify that outdated data (OE14) and flexibility for project developers to pick favourable values (OE12 and OE13) could lead to significant overestimation. Another source of potential overestimation is that the methodology determines carbon stocks at the start of each six-year baseline period and does not account for degradation that may occur during this period (OE11).

We recommend that the methodology improves clarity in various places, in particular by providing more guidance on forest definitions.

The methodology also has several elements that lead to underestimation. Most notably, the omission of some emission sources and carbon pools can lead to underestimation of emission reductions (UE1 to UE8). However, in most instances, such exclusions are optional and have a relatively low impact. Uncertainty discounts may also contribute to underestimation (UE9 to UE11). However, these are only applied in some instances. Therefore, in our assessment the risks for overestimation considerably exceed the potential sources of underestimation. In addition, some risks of overestimation have the potential to have a large impact. We note, however, that the degree of overestimation is likely to be considerably lower than with the older Verra methodologies. Future research on the application of the methodology will provide more clarity on the degree and frequency of the identified overestimation risks.

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