Guidelines on the application of the Methodological Framework Number 4

On Uncertainty Analysis of Emission Reductions

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Contents

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With respect to Criteria 7, 8 and 9, the Carbon Fund Participants clarify the following.

1. Uncertainty analysis by REDD Countries

1.1 Conducting an uncertainty analysis:

1. Criteria 7, 8 and 9 of the Methodological Framework require the ER program to conduct an uncertainty analysis which consists of a three-step process laid-out in three different criteria: identification (Criterion 7); reduction (Criterion 8) and quantification (Criterion 9).
2. Although the relevant Criteria on uncertainty analysis requires uncertainty analysis be conducted for both the Reference Level and monitoring of GHG emissions, the final objective of the Uncertainty Analysis is to provide an estimate of uncertainty of Emission Reductions in the form of the relative half-width confidence interval[1] at the 90% confidence level.
3. Therefore, REDD Countries shall conduct an uncertainty analysis for the Emission Reduction estimation in the following way:
    a. Criterion 7: Identification of source(s) of uncertainty and assessment of the relative contribution of each source to overall uncertainty of Emission Reductions.
    b. Criterion 8: Managing and reducing uncertainty of activity data and emission factors by minimizing (i) systematic errors (bias) through the implementation of Standard Operating Procedures (SOPs) and Quality Assurance / Quality Control (QA/QC) Procedures and (ii) random errors by other means (e.g. sampling intensification).
    c. Criterion 9: Quantification of the residual uncertainty of the estimates of ERs and its reporting.
4. REDD Countries shall adhere to the guidelines stated below when evaluating an ER program's Uncertainty Analysis. Additionally Chapter 3, Volume 1 of the 2006 IPCC Guidelines (and its 2019 refinement) and the GFOI MGD provides guidance that may complement the below requirements.
5. Although this quantitative measure of uncertainty pertains only to random errors, systematic errors (bias) should be reduced as far as practical s. If errors cannot be reduced further, the conservativeness principle shall apply For instance, a systematic error that causes an underestimation of the Emission Factor will always lead to an underestimation of Emission Reductions. REDD Country Participants may use conservative approaches in order to address systematic errors that are not practical to be further minimized.
6. The Uncertainty Analysis may also serve countries to reduce the Uncertainty of ERs over time. The ER Program Buffer has in place a mechanism to address the risk of uncertainty by applying an uncertainty discount to reported ERs, but also an incentive mechanism that will release Uncertainty Buffer ERs with the reduction of uncertainty. REDD Country Participants are strongly encouraged to have in place an improvement process to manage and reduce the uncertainty of monitored and reported ERs, including systematic and random sources of uncertainty. Identification of areas for improvement shall be described in the ER MR.
7. The Guidelines provided in this document assumes that the following techniques are employed for estimating the Activity Data, Emission Factors and Integration. The Guideline will be updated as necessary for countries applying different methods.:

[1] Also known as the relative margin of error.

a. Activity Data for deforestation, forest degradation and enhancement of carbon stocks is based on an approach which provides estimates of standard error (e.g. stratified sampling or systematic sampling).
b. Emission Factors are estimated with terrestrial inventories which provide estimates with known sampling variance.
c. Integration is based on estimated averages of AD and EFs.

1.2 Identification, assessment and addressing source(s) of uncertainty

8. As part of the first step of the Uncertainty Analysis, REDD Country Participants shall identify and discuss in qualitative terms the main source(s) of uncertainty, systematic or random, and shall conclude whether the contribution of each individual source to total uncertainty of Emission Reductions[2] is high or low[3]. Table 2 provides a list of the main source(s) of uncertainty that, at minimum, shall be evaluated qualitatively by REDD Country Participants, together with an indication on whether their contribution to overall uncertainty is typically high or low and whether they are systematic or random in nature[4]. If a REDD Country Participant decides to deviate from the indication, this shall be duly justified.
9. The qualitative analysis of the main source(s) of uncertainty the REDD Country Participant shall discuss the measures that have been implemented to manage and reduce these sources of uncertainty. Source(s) of uncertainty with a high contribution to the overall uncertainty shall always be managed and reduced by the REDD Country Participant. The strategy to reduce these sources varies depending on the type of error as explained below; Table 2 provides the proposed strategy to address the different sources of uncertainty.

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[2] It is important to note that the contribution of source(s) of error to total uncertainty relates to ERs, not GHG emissions, so the implications of different parameters may vary as certain parameters may be fully correlated between the Reference Level and the monitoring having little impact on Uncertainty of ERs For instance, usually Emission Factors are the same for RL setting and GHG monitoring, Emission Reductions can be expressed as the difference in the activity data in the Reference Period and the Monitoring Period multiplied by the Emission Factor (i.e. $\propto (AD_{RL} - AD_{Monitoring})$).

[3] See Chapter 5 GFOI (Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests) for further guidance.

[4] It is assumed that the country has applied sampling approach to derive activity data and emission factors. This guideline will be updated in the near future to consider other cases, such as when model based estimators are used to derive activity data and emission factors. It is important that the "meta-uncertainty" is also considered, this is that we are also uncertain about our uncertainty, and that we can reduce both (that is, estimate can become more certain, as can our estimate of its uncertainty). Meta-uncertainty should not be assumed to be zero and it should be discussed what are the underlying uncertainties.

Table 1 . Sources of uncertainty to be considered under the FCPF MF. Cells with H/L are used to indicate where the ER Program is required to assess the contribution to overall uncertainty of that particular component. Cells with YES/NO indicate that it is the ER Program's choice in how they deal with the particular component. The cells labelled without a choice (e.g. H, Yes, No) are prescribed

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
Activity Data						
Measurement	☑	☑	This source of uncertainty is applicable to cases where activity data is based on sampling. This is linked to the visual interpretation of operators and/or field positioning and it may be the origin of both systematic and random errors. Usually this source of error is high as evidenced by recent studies. Quantification methods for this source of error are in a research phase and have not been applied in operational contexts. Therefore, countries shall address this through robust QA/QC procedures that address both systematic and random error. Robust QA/QC procedures include: • Written Standard Operating Procedures including detailed labelling protocols; • Use of adequate[5] source of imagery and multiple imagery sources for labelling. • Training procedures for interpreters, to ensure the correct implementation of SOPs; • Re-interpretation of a number of sample units to ensure that SOPs are implemented correctly and identify areas for improvement.	*H (bias/random)*	*YES*	*NO*

[5] Adequate means at least 30 meters of spatial resolution and enough coverage to enable the assessment of the whole monitoring period.

Sources of uncertainty	**Systematic**	**Random**	**Analysis of contribution to overall uncertainty**	**Contribution to overall uncertainty (High / Low)**	**Addressed through QA/QC?**	**Residual uncertainty estimated?**
Representativeness	☑	☒	This source of uncertainty is related to the representativeness of the estimate which is related to the sampling design. If the sample is not representative for the area of interest or the time of interest (e.g. not all elements of the population or region of interest are included in the sampling frame; . deforestation is not measured for the period of interest), the estimate given by the sample will not be representative and this can be a cause of bias. Biases must be avoided as far as practical and this can be avoided through a correct sample design which can be ensured through adequate QA/QC processes. This source of uncertainty might be High or Low depending on the circumstances and REDD Countries may assess the magnitude.	*H/L (bias)*	*YES*	*NO*
Sampling	☒	☑	Sampling uncertainty is the statistical variance of the estimate of area for the applicable forest transitions that are reported by the ER Program. This source of error is random, but the selection of the estimator might be a source of error. ER Programs shall use reference data and unbiased estimators for estimating activity data and its uncertainty, as recommended by the GFOI MGD. See FAQ on area estimation and section 5.1.5 of the MGD(GFOI 2016), *Good practices for estimating area and assessing accuracy of land change* by Olofsson et al. (2014), for more information on how estimates can be produced using unbiased estimators of activity data.	*H (random / bias)*	*YES*	*YES*

Sources of uncertainty	**Systematic**	**Random**	**Analysis of contribution to overall uncertainty**	**Contribution to overall uncertainty (High / Low)**	**Addressed through QA/QC?**	**Residual uncertainty estimated?**
			Selection of a proper estimator would also be a source of uncertainty which would be addressed via QA/QC procedures.			
Extrapolation	☑	☒	This source of uncertainty is relevant when a stratified estimation (i.e. forest cover change map as stratification and sample) is applied. This source of uncertainty is related to the extrapolation of an estimate of the population to subpopulations which may lead to bias. In some cases ER Programs have estimated a variable of interest at the level of the Accounting Area, such as deforestation in hectares, and then they have inferred the variable of interest per forest type using a map, e.g. deforestation is 1000 ha according to the sample, the maps indicates that 30% of deforestation is in forest type A and 70% in forest type B, so it is inferred that 300 ha of deforestation in forest type A and 700 ha in forest type B based on the map areas. This source of error may be a source of bias which is difficult to quantify. 2006 IPCC guidelines, state that "...*where biases cannot be prevented, it is good practice to identify and correct them when developing a mean estimate*...". ER Programs should avoid using these methods and if they are not able to avoid them, they should justify if this will lead to an overestimation of Emission Reductions and apply any corrective measures. These errors may be avoided with QA/QC procedures. This source of uncertainty might be High or Low depending on the circumstances and REDD Countries may assess the magnitude.	*H/L (bias)*	*YES*	*NO*
Approach 3	☑	☒	This source of uncertainty exists when there is no tracking of lands or IPCC Approach 3. This occurs in cases when, for instance, an ER Program conducts two independent surveys to estimate activity data in period 1 and period 2 (e.g. dividing the reference period in two	*H/L (bias)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
			subperiods) without conducting tracking of lands. In this example, there is a risk that transitions are counted twice. For instance, if a unit of land transits from forest to non-forest, and then back to forest and then non-forest, there is a risk that deforestation is "double counted" if there is not a system to ensure tracking of lands. Solutions in this case are to avoid independent surveys (through permanent sample units) or to define transition rules and ensure that interpreters look at the past history of the sample unit to ensure that the transitions rules are respected. This is mitigated through the introduction of strong QA/QC measures.			
Emission factor For a detailed description and discussion of these errors, see e.g. Temesgen et al. 2015, Chave et al. 2004, Chave et al. 2005, Molto et al. (2012), Hunter et al. (2013), Chave et al. 2014, Picard et al. 2015, Picard et al. 2016, Kearsly et al. 2017 ,Weiskittel et al., 2015.						
DBH measurement	☑	☑	Measurement of DBH, height, and plot delineation are subject to errors. Errors may be caused by multiple factors such as poor training, poor measurement protocols, etc. While measurement errors are significant at the tree level, they usually average out at plot level and inventory level (Chave et al. 2004). Picard et al. (2015) also found the measurement error to be small when compared to the other errors. The FMT conducted an assessment of the contribution of this source of error (c.f. Annex) and found that this source of error should be negligible for Emission Reduction estimation, provided minimal QA/QC procedures are in	*H (bias) & L (random)*	*YES*	*NO*
H measurement	☑	☑		*H (bias) & L (random)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
Plot delineation	☑	☑	place. The contribution of this source of error to random error is low, yet QA/QC procedures should be in place to avoid systematic errors.	*H (bias) & L (random)*	*YES*	*NO*
Wood density estimation	☑	☑	This source of error pertains the selection of wood density. Many allometric equations rely on wood specific gravity - WSG (also referred to as basic wood density) as one of the independent variables. WSG is usually not measured, which is acceptable, but sourced from scientific publications and databases such as http://www.globallometree.org (registration required), the Global Wood Density Database (Chave et al. 2009, Zanne et al. 2009) or the 2006 IPCC guidelines. The random error from the use of WSG is low, but the lack of QA/QC procedures can lead to high systematic errors, this includes having strong protocols to identify the tree species and decision trees to attribute WSGs to each tree.	*H (bias) & L (random)*	*YES*	*NO*
Biomass allometric model	☑	☑	Allometric models/equations include several sources of uncertainty: • Choice of the allometric equation • Uncertainty attached to estimated model coefficients and the residuals of the model According to Picard et al. (2015) and Chave et al. (2014) the main source of uncertainty is the selection of the allometric equation. The lack of validation of the allometric equation should be considered as a source of bias, discussed, and addressed as far as practical by the REDD Country. QA/QC procedures shall be in place to ensure that the best allometric model is used and that any identified bias have been addressed. If bias is identified and this could lead to an	*H (bias) & H/L (random)*	*YES*	*YES/NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
			overestimation of Emission Reductions, this could be addressed by making the allometric model more conservative through the application of correction factors. In terms of uncertainty attached to the model coefficients, according to Chave et al. (2014), the prediction uncertainty of their pantropical allometric equations at plot level ranges from 10-15% for plots of 0.25 ha and 5-10% for plots of 1 ha, and this could result in 5.31% for estimates of aboveground biomass stocks. In terms of uncertainty of Emission Reductions it is expected that the contribution of this source of error is low due to interactions with other sources (c.f. Annex). However, REDD Countries shall discuss the source of random error and demonstrate that its contribution to overall uncertainty is low. If the contribution of this source to the uncertainty of total biomass (not Emission Reductions) is lower than the contribution of sampling error, this source of error may be neglected. If it cannot be neglected, it shall be propagated. If Countries are not able to propagate this source of error through MC simulation (i.e. no covariance matrix available, lack of capacity) they may increase the sampling uncertainty of AGB or/and BGB by 10% at 90% confidence level using the quadrature approach[6] and the combined error shall be propagated in the MC simulation.			
Sampling	☒	☑	This is applicable for cases when the carbon densities of forest used to derive emission factors are based on a terrestrial inventory based on a probabilistic design. Sampling uncertainty is	*H (random / bias)*	*YES*	*YES*

[6] For instance, if the sampling uncertainty is 10% and the allometric model uncertainty is 10%, the resulting uncertainty is sqrt(10%^2+10%^2) = 14%

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
			the statistical variance of the estimate of aboveground biomass, dead wood or litter. This source of uncertainty is random. Selection of a proper would also be a source of uncertainty which is systematic and would be addressed via QA/QC procedures.			
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	☑	☑	Some other parameters are used to estimate emission factors, such as emission factors, aboveground biomass in non-forest land and root-to-shoot ratios. These are usually not measured but sourced from scientific publications, databases or the 2006 IPCC Guidelines. This can lead to both random and systematic errors. The random error of each individual parameter might be low but the aggregated effect might be high. Moreover, the lack of QA/QC procedures for the selection of the values may lead to high systematic errors.	*H (bias / random)*	*YES*	*YES*
Representativeness	☑	☒	This source of uncertainty is related to the representativeness of the estimate which is related to the sampling design. If the sample is not representative for the area of interest (i.e. each element in area of interest has a known inclusion probability >0 and some random process is used to select elements), the estimate given by the sample will not be representative and can cause bias. Biases must be avoided <u>as far as practical</u> and this can be avoided through a correct sample design which can be ensured through adequate QA/QC processes.	*H/L (bias)*	*YES*	*NO*
Integration						
Model	☑	☒	The combination of AD & EF does not necessarily need to result in additional uncertainty. Usually, sources of both random and systematic error are the calculations themselves (e.g.	*H/L (bias)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimated?
			mistakes made in spreadsheets) and the process of data preparation (e.g. pre-processing, data cleansing, data transfer, etc). All models are simplification of reality, and this simplification could be a source of bias to emission reductions. All these sources are addressed with adequate QA/QC processes.			
Integration	☑	☒	This source of uncertainty is related to the lack of comparability between the transition classes of the Activity Data and those of the Emission Factors. Activity Data is usually estimated through remote-sensing observations, whereas Emission Factors for a specific forest type could be based on ground-based observations of the forest type. These may not be comparable, and it may represent a source of bias.	*H/L (bias)*	*YES*	*NO*

1.3 Uncertainty of the estimate of Emission Reductions

10. ER Programs shall apply Monte Carlo methods (IPCC Approach 2) for quantifying the Uncertainty of the RL and Emission Reductions. The source(s) of uncertainty that shall be propagated are provided in the right column of Table 1.
11. The Monte Carlo method shall be capable of handling correlation between input variables either through variance-covariance matrices (if these exists) and by ensuring that parameters used in both setting the Reference Level and during monitoring (i.e. same carbon fraction does not appear as a parameter under the reference level and the monitored estimates) are only propagated once.
12. ER Programs shall report transparently the parameters that are subject to the Monte Carlo simulation, the type of Probability Distribution Function (PDF) including its parameters, the source of assumptions made, as shown in the applicable table of the ER-MR template. The PDF shall be well justified and shall adhere to the guidance provided in Section 3.2.2.4 of Chapter 3, Volume 1 of the 2006 IPCC Guidelines (and its 2019 refinement). When the parameter is based on sample data, Bootstrap methods may be applied in substitution of the PDF definition. The following decision tree shall be used to define the PDF.

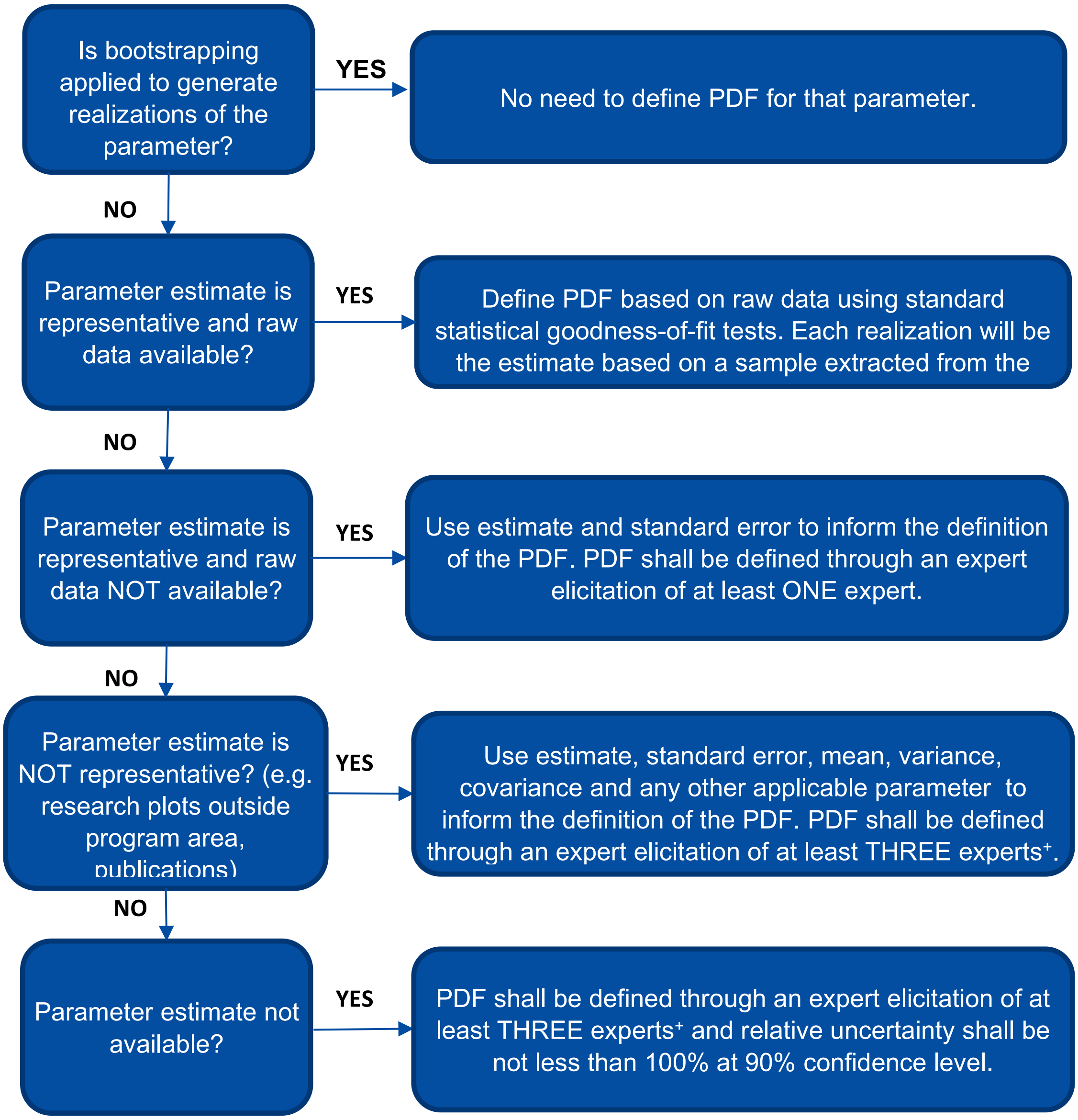

Figure 1 Decision tree for the definition of PDF.

+ Experts shall be asked independently of each other so that they are not aware of and therefore not biased by, each other's assessments, and (2) whatever width that is thusly derived that it is subsequently doubled in order to get the true estimate of whatever uncertainty is being solicited

13. Expert elicitation shall follow the provisions of Section 3.2.1.3 and 3.2.2.3 of Volume 1, Chapter 3 of the 2006 IPCC GL. Experts involved in expert elicitation shall be scientists, researchers or technicians who have relevant experience in the applicable ecosystems and domain within the REDD Country. The REDD Country shall provide in the ER-MR relevant information on the expert judgement as described in Page 3.41 Volume 1, Chapter 3 of the 2006 IPCC GL.

14. Indicators 9.2 and 9.3 distinguish reporting under integrated or non-integrated methods. All ER Programs shall report the uncertainty of aggregated Emission Reductions at the 90%

confidence level, except for those that use proxies[7] to estimate GHG emissions from forest degradation. In these cases, uncertainty of ERs shall be reported for forest degradation and for the aggregate of the other activities. Results of the simulation shall be reported transparently in the applicable table of the ER-MR template

1.4 Sensitivity analysis and identification of areas of improvement of MRV system

15. ER Programs shall carry out a sensitivity analysis to identify the relative contribution of each parameter to the overall uncertainty of Emission Reductions. Relative contributions refer only to uncertainty estimates rather than contributions of systematic errors. Sensitivity analysis is conducting by switching off each source of uncertainty (listed in Table 1) at a time and assessing the impact to overall uncertainty of Emission Reductions.
16. Where individual source(s) of uncertainty are found to contribute significantly to a high overall uncertainty of the ER, ER Programs should consider reducing the uncertainty by improving methods, collecting additional or new data, etc. in the next monitoring event.
17. ER Programs shall maintain a reproduceable record of the sensitivity analysis so that it provides enough information for improvements in future monitoring events.

2. Uncertainty analysis assessment by Validation and Verification Bodies

18. It may be noted that the concept of materiality as defined in the Validation and Verification Guidelines, is distinct from the concept of uncertainty, which is defined in ISO 14064-2:2006 as "parameter associated with the result of quantification which characterizes the dispersion of the values that could be reasonably attributed to the quantified amount" which is related to random errors. There is no inherent relationship between random errors and materiality.[8]
19. Validation and Verification Bodies also play a role in the improvement process of the uncertainty analysis through the identification of opportunities for future technical improvements to the Forest Monitoring System which are raised in the form of Observations. The observations shall only identify opportunities for improvement and shall not include guidance for improving the system. If Observations are not taken into consideration during the subsequent verification, then the VVB may raise similar Observation at the next monitoring event.
20. Where individual source(s) of uncertainty are found to contribute significantly to a high overall uncertainty of the ER, ER Programs should consider reducing the uncertainty by improving methods, collecting additional or new data, etc. in the next monitoring event. The VVB shall confirm that this sensitivity analysis was completed, but shall not assess whether the conclusions of the sensitivity analysis were followed-up or taken into consideration. These results may be used by the VVB to identify areas for improvement for the REDD Country Participant.

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[7] Defined as "An indirect quantitative measure that approximates or represents activities in the ISFL ER Program Area in the absence of direct activity data that is consistent with IPCC guidelines". Under the FCPF this refers to methods that use logging volumes for estimation GHG emissions.

[8] Taking the Reference Level as an example, it is possible for a Reference Level to be calculated using highly uncertain data sources and, as such, to have a high degree of associated uncertainty. However, if the audit team is able to replicate the calculation of the RL and confirm that the RL is free from calculation errors and has been calculated in a manner consistent with applicable criteria, the extent of any discrepancy between the Reference Level and the VVB's recalculation may be quite small.

Annex – Simulation Example

In order to inform the development of these guidelines, the FMT conducted a MC simulation using the data from the Atiala-Atsinanana Emission Reduction Program for the RL establishment and the ex-ante Emission Reduction estimation (i.e. based on a 27% average performance and assuming the additional regeneration of 3,175.00 ha/year of secondary forest). The following sources of error were modelled and their contribution to Emission Reductions was estimated:

- Activity Data – Sampling error for both RL and Monitored estimates
- Emission Factor
  - Measurement error of DBH and H: % error sourced from Chave et al. (2015)
  - Allometric model error: Covariance matrix of parameters sourced from Vieilledent et al. (2015)
  - Sampling error of aboveground biomass
  - Error estimation of root-to-shoot ratio
  - Error estimation of other factors (e.g. carbon fraction)

In order to simplify the calculation process and align it to other ER Programs, only deforestation and AGB and BGB pools were considered for the simulations. Moreover, since the sampling uncertainty of AGB was very low for the ER Program (<5% at 90% confidence level), only 50% of sample units were considered so as to increase the uncertainty of Emission Factors and make it closer to other ER Programs (>10% at 90% confidence level).

A total of 10,000 simulations were conducted as recommended by the 2006 IPCC Guidelines. The PDFs were defined in compliance with these Guidelines.

Once the MC simulation was conducted, different sources of error were “disconnected” to assess how they would affect the overall uncertainty of Emission Reductions. Different scenarios were modelled: a) All parameters; b) No measurement uncertainty (DBH, H and WSH do not have uncertainty); c) No allometric model uncertainty (parameters of allometric model and residue do not have uncertainty); d) No sampling uncertainty for AGB; e) No Emission factor uncertainty; f) No Activity Data uncertainty.

The following table shows the relative half-width confidence interval at 90% confidence level for all the above scenarios. Uncertainty of Emission Reductions is much higher and the impact of Emission Factors of uncertainty of Emission Reductions is much lower:

Scenario	RL - Total	ER - Total
All parameters	25%	104%
No Measurement	24%	101%
No allometric	24%	100%
No sampling	23%	101%
No emission factor uncertainty	22%	99%
No AD uncertainty	10%	10%

The following table presents the deviation of each scenario from the scenario of 'All parameters' showing the relative importance of each source. In terms of Emission Reductions, Emission Factors would have a minimal contribution to overall uncertainty. Most of the uncertainty from Emission Factors could be explained from the sampling uncertainty, root-to-shoot ratios and other factors, probably because of interaction effects between measurement and allometric uncertainty with sampling uncertainty and other factors. Therefore, not considering measurement and allometric uncertainty would not lead to a significant underestimation of uncertainty of Emission Reductions.

Scenario	RL - Total	ER - Total
All parameters	0.0%	0.0%
No Measurement	2.1%	2.7%
No allometric	1.3%	3.5%
No sampling	7.6%	2.7%
No emission factor uncertainty	12.6%	4.9%
No AD uncertainty	59.4%	90.4%

Document information

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