MiLCA | Protocol for including Mitigation actions in Agricultural Lifecycle Assessment

Supplementary materials for consultation

Simmons, A.T[1]., Cowie, A.L.[2], Meyer, R.S.[3], Grant, T.[4], Macdonald, A. [3], Eady, S[4] Cheng, L. [5] and Eckard, R. [3]

[1] NSW Department of Primary Industries, Muldoon St, Taree NSW 2430 Australia

[2] NSW Department of Primary Industries, Trevenna Rd, Armidale NSW 2351 Australia

[3] The University of Melbourne, Royal Parade, Melbourne Victoria 3010 Australia

[4] Lifecycles, Smith Street, Collingwood VIC 3066, Australia

[5] The University of Melbourne, Dookie-Nalinga Road, Dookie College VIC 3647 Australia

Contents

1 Introduction

A key purpose of the MiLCA consultation is to obtain views on the appropriate level of statistical uncertainty for adjusting the estimated GHG emissions reduction (see section 9.2 of the protocol) and the magnitude of adjustment that should be made for the different levels of data quality (see section 8 of the protocol). These supplementary materials have been written to assist reviewers with assessing these issues. They are for the consultation process only and will not be included in the final protocol. Readers are encouraged to familiarise themselves with the content of the draft protocol prior to reading this document. All definitions and acronyms are consistent with the draft protocol.

This document has three sections in addition to this introduction. Section 2 provides background to the approaches used to make the adjustments for statistical uncertainty data quality. Section 3 presents sensitivity analysis of the impact of the confidence level (*i.e.* probability of exceedance), statistical uncertainty and data quality on $GHG_{adj_{t(0.6)}}$. The purpose of section 3 is to demonstrate to reviewers how the statistical confidence, statistical uncertainty of evidence used for calculations and data quality effect $GHG_{adj_{t(0.6)}}$. Section 4 provides a list of targeted questions for reviewers to respond to as part of the consultation process.

2 Background

2.1 Adjustment for uncertainty

Adjusting an estimate of a GHG emissions reduction based on statistical uncertainty is an approach that has been used in climate change mitigation policies to ensure a conservative estimate of emissions reduction Integrating this approach into the protocol was done to provide a high degree of confidence that an emissions reduction had occurred and to incentivise the use of emissions reduction estimates for which there is relatively low statistical uncertainty. An independent review (Independent Pricing and Regulatory Tribunal, 2013) confirmed the success of the approach to achieve the latter objective for the New South Wales (Australia) Greenhouse Gas Reduction Scheme (GGAS) as indicated by the statement “The inclusion of a ‘discounting for uncertainty’ approach, sometimes referred to as the ‘70% rule’, which discounted carbon estimates based on the level of uncertainty around those estimates, created a very tangible commercial driver for reducing error and uncertainty in measurement processes.”.

Discounting for uncertainty has been incorporated in policies and schemes in addition to the GGAS. Methods in the federal Australian government's emission reduction scheme (the Australian Carbon Credit Unit (ACCU) scheme), for example the Soil Carbon Sequestration method, use statistical uncertainty as a basis for conservativeness. It is also a key requirement for methods developed by Verra (Verra Carbon Standard, 2022) and was also used by the Chicago Climate Exchange (CCX) while it was operational.

The way statistical uncertainty is used to adjust an emissions reduction claim between the above examples differs from the application of the concept in the protocol. Those examples used the statistical uncertainty of field measurements or modelled estimates of soil carbon stocks, or avoided GHG emissions, to make the adjustment. In contrast, the protocol adjusts the estimated emissions reduction based on the statistical uncertainty of the scientific evidence used to support a claim of an emissions reduction. This approach has been used to ensure the protocol is workable and cost effective. As an example, if DMD of intake was required for calculations then would compel a dairy farmer to take a suitable number of pasture cuts prior to each grazing and send them for laboratory analysis – a time consuming and costly exercise that would make the protocol unworkable.

The magnitude of the discount differs between schemes. For example, the GGAS credited reductions for the value for which there was a 70% chance of exceedance, the Soil Carbon method credits reductions for which there is a 60% chance of exceedance and the CCX discounted estimated sequestration by twice the reported standard deviation at 90% confidence interval. Verra uses a relatively complex approach that results in ~10% reduction in the abatement that can be claimed. For comparison, the 60% chance of exceedance used in the Soil Carbon method results in a reduction of ~16% to abatement that is awarded. The draft protocol was developed with an adjustment for uncertainty based on a 60% chance of exceedance. This value was chosen to illustrate the concept and calculation procedure and should not be considered a recommendation by the project team. Sensitivity analysis is presented in section 3 using the data from the worked exampled in Appendix C and Appendix D of the draft protocol to demonstrate the effect of changing the level of confidence on $GHG_{adj_{t(0.6)}}$.

2.2 Data quality approach

The accuracy of a carbon footprint (CF) and/or GHG emissions reduction estimate is dependent on the quality of data that are used in calculations. In the context of this protocol, data quality is the relevance to the system being assessed of the primary or secondary data used in emissions reductions calculations. The approach for data quality adjustment integrated into the protocol adds statistical uncertainty to the calculations for $GHG_{adj_{t(0.6)}}$ except where the highest level of data quality (*i.e.* on-farm data from the system being assessed) is used thereby increasing the prediction interval. As can be seen in equation in section 9.2, increasing the statistical uncertainty to the calculation results in a reduction in the claimable emissions reduction.

The data quality adjustment was incorporated into the protocol for two purposes. The absence of an adjustment when the highest quality data is used incentivises users to collect high quality data with which to calculate a GHG emissions reduction claim. The second purpose was to minimise claims of greenwashing. Making industry wide claims of GHG emissions reductions based on data that has little to no relevance to the system being assessed would expose the protocol to criticism. Adjusting the claimable emissions reduction to account for the use of low-quality data removes this potential source of criticism.

The approach used in the protocol is adapted from the global guidance for life cycle assessment (LCA; Ciroth et al., 2016) with the data quality categories and levels within each category modified to suit the protocol. The approach used here of generating a value that can add uncertainty to a calculation is also a modification of the LCA framework, the purpose of which is to estimate the confidence around a LCA model output using Monte Carlo analysis.

2.3 Location of data quality adjustment in equations

The data quality adjustment has been incorporated into the variance of the equations used to calculate $GHG_{adj_{t(0.6)}}$. The intention behind this decision was that, where a multiple regression equation is used, the data quality of a datum used to populate an equation would adjust the relevant variance component. Feedback prior to consultation suggested that it may be more appropriate for the data quality adjustment to be applied to the mean value (*i.e.* $\bar{x}_d$ where results from an experiment that compares two means is used (Equation 3 of the protocol), or $\hat{y}$ where a regression approach is used). Locating the data quality adjustment within the variance term means technologies with experimental results that have a relatively high statistical uncertainty receive a greater adjustment than a technology with experimental results that have a relatively low statistical uncertainty. However, the claimable GHG emissions reduction is also determined by the quality of the primary and/or secondary data used in the calculation, as discussed in section 8 of the protocol, and the quality of these data is independent of the experiment that was conducted to assess the GHG emissions reduction associated with the implementation of the technology. Hence, it may be more appropriate to apply the data quality adjustment to the mean value.

3 Sensitivity analysis

3.1 Statistical uncertainty and probability of exceedance

Sensitivity analysis was done to assess the impact of statistical uncertainty and the probability of exceedance (*p*) on $GHG_{adj_{t(p)}}$ using data from the worked examples of the draft protocol. To demonstrate the impact of statistical uncertainty on $GHG_{adj_{t(p)}}$, the data used in the worked examples of the drat protocol were adjusted to be 0.5 1.5 or 2 times the reported statistical uncertainty. To demonstrate the impact of *p*, and interactions with statistical uncertainty, on $GHG_{adj_{t(p)}}$, $GHG_{adj_{t(p)}}$ was calculated for *p* values of 0.6, 0.7, 0.8, 0.9 and 0.95 for all levels of statistical uncertainty.

For the calcium cyanimide example, with no change to the reported statistical uncertainty, an increase in *p* from 0.6 to 0.95 resulted in an approximately 7-fold increase in $GHG_{adj_{t(p)}}$ (Table 1). At a *p* of 0.9, $GHG_{adj_{t(p)}}$ is greater than 1, so there would be no claimable emissions reduction associated with the use of calcium cyanimide.

The decrease or increase in $GHG_{adj_{t(p)}}$ associated with a change in statistical uncertainty reflected the magnitude of the change in uncertainty (*e.g.* a doubling in uncertainty doubled $GHG_{adj_{t(p)}}$). When the statistical uncertainty was assumed to be twice that reported for the relevant experiment, the *p* at which a GHG emissions reduction could no longer be claimed reduced to 0.8.

Table 1 $GHG_{adj_{t(p)}}$ (and difference from SE) for the calcium cyanimide analysis presented in Appendix C of the draft protocol assuming 0.5, 1, 1.5 and 2 times statistical uncertainty (SE), p of 0.6, 0.7, 0.8, 0.9 and 0.95 and no data quality adjustment.

P	**Statistical uncertainty**			
	0.5 *SE*	***SE***	**1.5 *SE***	**2 *SE***
0.6	0.11(-0.11)	0.22(0)	0.32(0.1)	0.43(0.21)
0.7	0.23(-0.22)	0.45(0)	0.67(0.22)	0.89(0.44)
0.8	0.37(-0.37)	0.74(0)	1.11(0.37)	1.47(0.73)
0.9	0.60(-0.60)	1.20(0)	1.80(0.60)	2.40(1.20)
0.95	0.84(-0.83)	1.67(0)	2.5(0.83)	3.33(1.66)

For the 3-NOP example, doubling the statistical uncertainty increased $GHG_{adj_{t(p)}}$ by between 1 and 5%. Halving the statistical uncertainty reduced $GHG_{adj_{t(p)}}$ by between 1 – 4%. Increasing the *p* value reduced the claimable emissions reduction, with $GHG_{adj_{t(0.95)}}$ 23% greater than the unadjusted median value (*i.e.* $GHG_{adj_{t(0.5)}}$; data not shown) and 18% greater than the value for $GHG_{adj_{t(0.6)}}$ used in the worked example.

Table 2 $GHG_{adj_{t(p)}}$ (and difference from RMSE) for the 3-NOP analysis presented in Appendix D of the draft protocol assuming 0.5, 1, 1.5 and 2 times statistical uncertainty (RMSE), p of 0.6, 0.7, 0.8, 0.9 and 0.95 and no data quality adjustment.

P	**Statistical uncertainty**			
	0.5 *RMSE*	***RMSE***	**1.5 *RMSE***	**2 *RMSE***
0.6	0.55(-0.01)	0.56(0.00)	0.56(0.00)	0.56(0.00)
0.7	0.56(-0.02)	0.58(0.00)	0.58(0.00)	0.59(0.01)
0.8	0.58(-0.02)	0.60(0.00)	0.61(0.01)	0.62(0.02)
0.9	0.60(-0.03)	0.63(0.00)	0.65(0.02)	0.67(0.04)
0.95	0.62(-0.04)	0.66(0.00)	0.69(0.03)	0.71(0.05)

3.2 Data quality

For the data quality sensitivity analysis, data from both worked examples were used to calculate $GHG_{adj_{t(p)}}$ assuming all data used were either highest quality, level 2, level 3 or lowest quality, for *p* of 0.6, 0.7, 0.8, 0.9 and 0.95.

Sensitivity for the $CaCN_2$ worked example (Table 3) and for the 3-NOP worked example (Table 4) showed that $GHG_{adj_{t(p)}}$ increased as data quality decreased, hence the claimable emissions reduction became more conservative as data quality decreased for all values of *p*. Further, the difference in $GHG_{adj_{t(p)}}$ between the highest and lowest levels of data quality was greater for relatively high levels of *p* compared to relatively low levels of *p*. Moving from the highest to lowest quality of data when *p* = 0.6 reduced the claimable emissions reduction by 22 and 2%, for $CaCN_2$ and 3-NOP respectively, and that increased to a 17% reduction when *p* = 0.95 for 3-NOP.

Increasing *p* for the $CaCN_2$ example resulted in no claimable emissions reduction with *p* = 0.95 when the highest quality data was used and *p* = 0.8 when the lowest quality data was used. For the 3-NOP example, increasing *p* from 0.6 to 0.95 reduced the claimable emission reduction by 18% when the data quality was highest and 43% when data quality was lowest.

These results demonstrate that data quality can have a greater impact on $GHG_{adj_{t(p)}}$ than statistical uncertainty of the experimental results being assessed by the protocol. Further, by comparing the results for $CaCN_2$ and 3-NOP, that used experimental results with different levels of statistical uncertainty, it is clear that the change in $GHG_{adj_{t(p)}}$ associated with a decline in data quality was influenced by the uncertainty of the experimental results.

Table 3 $GHG_{adj_{t(p)}}$ (and difference from highest data quality level) for the calcium cyanimide analysis presented in Appendix C of the draft protocol assuming data quality levels from highest (i.e. no data quality discount) to lowest, with p of 0.6, 0.7, 0.8, 0.9 and 0.95.

p	**Data quality**			
	Highest	**Level 2**	**Level 3**	**Lowest**
0.6	0.14(0)	0.19(0.05)	0.26(0.12)	0.33(0.19)
0.7	0.29(0)	0.4(0.11)	0.54(0.25)	0.7(0.41)
0.8	0.48(0)	0.66(0.18)	0.88(0.4)	1.15(0.67)
0.9	0.78(0)	1.07(0.29)	1.44(0.66)	1.87(1.09)
0.95	1.09(0)	1.49(0.4)	1.99(0.9)	2.6(1.51)

Table 4 $GHG_{adj_{t(\alpha)}}$ (difference from highest data quality level) for the 3-NOP analysis presented in Appendix D of the draft protocol assuming data quality levels from highest (i.e. no data quality discount) to lowest, with p of 0.6, 0.7, 0.8, 0.9 and 0.95.

p	**Data quality**			
	Highest	**Level 2**	**Level 3**	**Lowest**
0.6	0.56(0.00)	0.56(0.00)	0.57(0.01)	0.58(0.02)
0.7	0.58(0.00)	0.59(0.01)	0.61(0.03)	0.63(0.05)
0.8	0.60(0.00)	0.62(0.02)	0.65(0.05)	0.68(0.08)
0.9	0.63(0.00)	0.67(0.04)	0.71(0.08)	0.76(0.13)
0.95	0.66(0.00)	0.71(0.05)	0.76(0.10)	0.83(0.17)

3.3 Discussion

Key points from the analysis above

Where an increase in the p value used to calculate $GHG_{adj_{t(p)}}$ *results in no claimable GHG emissions reduction it is due to the statistical uncertainty of experimental results being relatively high.*

For the $CaCN_2$ example, no emissions reduction could have been claimed when the *p* value increased to 0.95 when the highest data quality was assumed. It needs to be considered that;

- The experiment that provided the results for the $CaCN_2$ example had a relatively low number of replicates (*n*). The low *n* resulted in a higher critical *t* value than would have been generated if a greater *n* had been used in the experiment, resulting in a relatively $GHG_{adj_{t(0.95)}}$. This was demonstrated by calculating $GHG_{adj_{t(0.95)}}$ using the data for the $CaCN_2$ example but assuming *n* = 20. When *n* = 20, the critical *t* value changed from 2.35 to 1.72 and reduced $GHG_{adj_{t(0.95)}}$ from 1.09 to 0.88 (data not shown).
- The *SE* of the control group from the experiment was relatively high (~ 50% of the mean) and would have been lower if *n* was greater, as *SE* is a function of *n*. The reason that the results from the experiment were significant at the required level ($p < 0.05$) is because the effect of the $CaCN_2$ on methane emissions was so strong.

Hence, we can consider that no claimable emissions reduction occurring when $p = 0.95$ for the $CaCN_2$ example was primarily the result of an experimental design with low *n* resulting in relatively high statistical uncertainty, as opposed to the calculation method being inappropriate.

In contrast to $CaCN_2$ experimental results, the results relied upon for the 3-NOP worked example were more statistically robust. This resulted in a claimable emissions reduction from the use of 3-NOP even when the lowest quality data was used.

The data quality adjustment can have a greater impact on $GHG_{adj_{t(p)}}$ *than the adjustment for statistical uncertainty and the effect of data quality is dependent on statistical uncertainty.*

The results presented here demonstrate that data quality can have a greater impact than p on $GHG_{adj_{t(p)}}$ and because the data quality adjustment is located within the variance term, the magnitude of the data quality adjustment is dependent on the statistical uncertainty of the evidence used for calculations as demonstrated by the sensitivity analysis presented above.

Moving the data quality adjustment to the mean value (*i.e.* $\bar{x}_d$ or $\hat{y}$) may still result in data quality having a greater effect on $GHG_{adj_{t(p)}}$ and this would be dependent on the values used to adjust the mean value for data quality. However, the data quality adjustment would be more consistent between farms that are assessed because it is not magnified by the statistical uncertainty of the experimental results used to calculate the GHG emissions reduction.

4 Targeted questions

Below is a list of targeted questions for reviewers to consider and, where necessary, provide feedback on the supplied form.

1. Considering the information above, and any additional information the reader has access to that they may feel is relevant, what is the appropriate value for *p*?

The draft protocol used $p = 0.6$ as a starting point for the process of determining the appropriate value for *p.* Keeping in mind that experimental results used to calculate $GHG_{adj_{t(p)}}$ shall have demonstrated a statistically significant ($p < 0.05$) difference/relationship, the *p* value determines the discount on a claimable emissions reduction based on the distribution of expected values from the statistical analysis. The most appropriate way to consider this question is “how confident do we want to be in the claimed emissions reduction?”. Where $p = 0.6$ we can be confident that the claimed GHG emissions reduction for a given piece of evidence, prior to adjustment for data quality, will be less than the actual GHG emissions reduction 60% of the time. For $p = 0.95$ we can confident that this will occur 95% of the time. The appropriate value for *p* needs to be determined and needs to reflect the level of confidence that an emission reduction has occurred required by a supply chain and/or policy to inform decisions.

2. What is the minimum applicable data quality for each data category? Are data that are the equivalent of IPCC tier 1 data suitable? Are data that have a data quality that is lower than IPCC tier 1 in any data quality category appropriate?

Adjusting an emissions reduction for data quality makes the estimate more conservative and increases the confidence that the claimed GHG emissions reduction will be less than the actual GHG emissions reduction. For the $CaCN_2$ and 3-NOP worked examples, the values for $GHG_{adj_{t(0.6)}}$ calculated in the worked examples are the equivalent to being confident that the claimed GHG emissions reduction will be less than the actual GHG emissions reduction 72% and 65%, respectively (*i.e.* the data quality adjustment added a 12 and 5% increase in confidence level for $CaCN_2$ and 3-NOP, respectively).

When sourcing data to calculate a claimable emissions reduction a minimum quality of data needs to be determined. The current suggestions for suitable data qualities for each category are shown in Appendix A of the draft protocol. Consideration of the minimum level of data quality that can be used in the protocol needs to be made. The IDF carbon footprinting guidance allows the use of tier 1 IPCC data when calculating carbon footprints so allowing the equivalent of tier 1 data to calculate an emissions reduction would be consistent with the IDF guidance. For reference, IPCC tier 1 data, depending on what it represents, would be the equivalent of data quality levels of 2, 5, 4, 4 for Data source, System Likeness, Temporal and Geographical categories, respectively. The GHG Protocol, a set of standards and tools designed to facilitate the tracking of emissions reductions, also allows the use of tier 1 data. For clarity, data quality levels of 3 or lower for Data source and 5 for Geographical as shown in Appendix B of the draft protocol are lower than IPCC tier 1 data.

3. Is locating the data quality adjustment inside the variance term appropriate?

Locating the data quality adjustment inside the variance term means technologies with experimental results that have a relatively high statistical uncertainty receive a greater adjustment than a technology with experimental results that have a relatively low statistical uncertainty. However, the quality of the data used to calculate a claimable GHG emissions reduction is independent of the experiment that was conducted to assess the GHG emissions reduction associated with the implementation of the technology. Hence, it may be more appropriate to apply the data quality adjustment to the mean value. Adjusting the mean value for data quality will also make the magnitude of the adjustment more consistent across technologies because it will not be dependent on the variance.

4. Is the magnitude of the data quality adjustment that occurs for each level of data quality adjustment appropriate (Appendix B of protocol)?

The value used for each level of data quality determines the adjustment that is made for the quality of data to increase conservativeness. The values included in Appendix B of the draft protocol are suggested values. The impact of the value for the lowest quality data needs to be assessed to determine whether the adjustment for that level of data is appropriate. Table 5 shows the increase in the confidence that a claimed emissions reduction will be less than the actual emissions reduction that occurs as data quality declines, relative to the highest level of data quality that has a confidence level of 60%. It shows that when the lowest data quality is used then the confidence increases by a maximum 19% and 18% 3-NOP and $CaCN_2$, respectively, or the equivalent of a 79% and 78% confidence level. It also shows that the increase was greatest when p = 0.7.

Note, this question should be considered independently of question 3. If the DQ adjustment is moved to the mean, then the values for the data quality adjustment will be modified to ensure the relative change due to data quality will remain relatively unchanged.

Table 5 Increase in confidence that a claimed emissions reduction will be less than the actual emissions reduction for all levels of data quality relative to the highest level of data quality for 3-NOP/$CaCN_2$ for p of 0.6, 0.7, 0.8, 0.9 and 0.95.

p	**Data quality**			
	Highest	**Level 2**	**Level 3**	**Lowest**
0.6	0/0	4/4	8/8	13/12
0.7	0/0	6/6	13/12	19/18
0.8	0/0	7/7	14/12	17/16
0.9	0/0	6/5	9/8	10/9
0.95	0/0	4/3	5/4	5/5

5. Are the statistical approaches described by the equations in the draft protocol appropriate for their intended purpose? Do the equations cover the possible statistical analyses that could be used to analyse experiments to assess the efficacy of a technology?

The purpose of the equations in the draft protocol are to ensure that the claimable GHG emissions reduction is conservative. The issues of *p* value and data quality have been addressed in questions 1 – 3 (above) so this question relates to the statistical approach only, in particular the use of the prediction interval and the critical *t* score to adjust the GHG emissions reduction based on the statistical uncertainty of the evidence used.

6. What is the appropriate number of experiments required to demonstrate efficacy in an emissions reduction technology? Do any additional requirements need to be included when using a carbon credit method to demonstrate efficacy?

The draft protocol requires a minimum of three sets of experimental results to be presented to demonstrate efficacy of a technology. This criteria is met when using a meta-analysis because a meta-analysis will require the use of more than three sets of experimental results. Further, a method developed for a carbon credit scheme would also likely require multiple studies to support the development of the method however there is no specific requirement for this in the ICROA guidance.

7. Does the draft protocol achieve the purpose of ensuring emissions reductions associated with the implementation of a technology in a diary system are conservative and defensible?

The draft protocol uses a number of techniques to ensure that a claimed emissions reduction is conservative and defensible, and it needs to be decided whether these techniques, when combined, achieve that objective.

The techniques used in the draft protocol are;

- Demonstrating confidence in the efficacy of the technology (*i.e.* more than one study is required to demonstrate a statistically significant GHG emissions reduction for a technology to be considered efficacious)
- Ensuring that the research relied upon for calculations:

    - Has a statistically significant ($p < 0.05$) difference or relationship
    - Is published in a credible scientific journal
    - Is conducted under conditions that allow results to be transferred to a commercial system.
- Where a carbon credit method is used to demonstrate efficacy or as the basis of calculations, that method is part of a scheme that is accredited by the International Carbon Reduction and Offsetting Accreditation program
- Experimental results, results of a meta-analysis or a carbon credit method used to calculate a claimable GHG emissions reduction are relevant to the system being assessed.
- An emissions reduction is adjusted for the quality of data used to calculate the emissions reduction.
- The emissions reduction is adjusted for the statistical uncertainty of the evidence used to calculate an emissions reduction.

5 References

Ciroth, A., Muller, S., Weidema, B. and Lesage, P. 2016. Empirically based uncertainty factors for the pedigree matrix in ecoinvent. Int. J. Life Cycle Assess. 21(9), 1338-1348.

Independent Pricing and Regulatory Tribunal 2013 NSW Greenhouse Gas Reduction Scheme–Strengths, Weaknesses and Lessons Learned, https://www.ipart.nsw.gov.au/sites/default/files/documents/nsw_greenhouse_gas_reduction_scheme_-_strengths_weaknesses_and_lessons_learned_-_final_report_-_july_2013.pdf.

Verra Carbon Standard 2022 Methodology requirements, Verra Carbon Standards, https://verra.org/wp-content/uploads/2022/06/VCS-Methodology-Requirements-v4.2.pdf.