INDEPENDENT EXPERT REPORT: LIMITED SCOPE VVB ASSESSMENT OF TOOL FOR ESTIMATING ORGANIC CARBON STOCKS USING DIGITAL SOIL MAPPING

Methodology Title	Tool for Estimating Organic Carbon Stocks using Digital Soil Mapping (ID# VT0014)
Version	1.0
Sectoral Scope(s)	14. Agriculture, forestry and other land use (AFOLU)
Document Reviewed	VT0014 COPY 220825_230825
Date of Issue	26 August 2025
Expert Assessor	SCS Global Services
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1 INTRODUCTION

Verra is managing the development of a new VCS Tool for Estimating Organic Carbon Stocks using Digital Soil Mapping (ID# VT0014). Per section 2.1.2 of the *Methodology Development and Review Process, v4.4*, this methodology is being developed through an alternative process that has been deemed more efficient and equally robust. The alternative process included:

1) Replacement of Section 3.5 Step 5: Validation/verification body assessment of methodology with review by a group of independent experts and a limited scope VVB assessment.
2) Conducting the review of the revised draft after the public consultation by a VVB representative.

Based on their experience in the use of digital soil mapping for quantification of soil organic carbon stock and project development for the carbon market, Perennial Climate Inc. hired SCS Global Services to provide an expert assessment of the proposed methodology.

The Limited Scope VVB Assessment focused on:

1) Structure and clarity of methodology: Assessment of whether the methodology is written in a clear, logical, concise, and precise manner that will enable project developers to implement projects consistently and transparently report project results.
2) Soil organic carbon quantification approaches: Assessment of whether the approach for calculating SOC content and stocks is appropriate, adequate, conservative, in alignment with ALM methodologies (e.g., VM0042 and VM0032). This must also include an assessment of the consistency of the equations and parameters with the GHG sources in the baseline and project scenario and the monitoring parameters.
3) Verifiability: Assessment of whether the methodology is sufficiently clear and specific to require project developers to transparently report project results that can pass validation and verification with high confidence

2 ASSESSMENT APPROACH & FINDINGS

The expert assessor reviews the draft tool that was revised following the public consultation and provided feedback to Verra. Perennial Climate Inc. prepares responses to the expert assessor's findings and updates the methodology accordingly. The expert assessor reviews the responses and provides confirmation that the planned updates address the findings. See section 6 for detailed expert assessment feedback.

3 ASSESSMENT CONCLUSION

The expert assessor completed the expert assessment of the draft *Tool for Estimating Organic Carbon Stocks using Digital Soil Mapping* and confirms the draft methodology, and proposed updates adhere to the criteria established.

4 EXPERT QUALIFICATIONS

SCS Global Services is accredited by ANSI National Accreditation Board (ANAB) under ISO/IEC 17065:2012, evident from the ANAB official website and valid until 01/12/2025. Link to ANAB website. The information about SCS Global accreditation and sectoral scope is available at: https://anabpd.ansi.org/Accreditation/product-certification/AllDirectoryDetails?&prgID=1&OrgId=33&statusID=4

SCS Global Services have sufficient knowledge and experience of working on the projects in sectoral scope 14. Agriculture, Forest and Land Use, including agricultural land management projects.

5 SIGNATURE

Signed for and on behalf of:

Name of entity: SCS Global Services

Signature: _____

Name of signatory: DOUGLAS BALDWIN, PHD

Date: 26 AUGUST 2025

6 EXPERT FEEDBACK

Any potential or actual discrepancies identified during the assessment process were resolved through the issuance of findings. The types of findings typically issued by SCS during this type of engagement are characterized as follows:

- Non-Conformity Report (NCR): An NCR signified a discrepancy with respect to a specific requirement. This type of finding could only be closed upon receipt by SCS of evidence indicating that the identified discrepancy had been corrected.
- New Information Request (NIR): An NIR signified a need for supplementary information in order to determine whether a material discrepancy existed with respect to a specific requirement.
- Observation (OBS): An OBS indicates an area where immaterial discrepancies exist between the observations, data testing results or professional judgment of the audit team and the information reported or utilized (or the methods used to acquire such information) within the GHG assertion. A root cause analysis and corrective action plan are not required, but highly recommended. Observations are considered by the audit team to be closed upon issuance, and a response to this type of finding is not necessary.

OBS 1 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Section 5.1

Finding: Section 5.1 states: "The initial (t0) model validation and associated DSM-MVR is reviewed by an IME at project validation or at the first verification. Revalidations occur at least once every 5 years thereafter."

The audit team notes that an example template of the DSM-MVR that projects may use may prevent confusion and reduce the number of findings projects receive from the VVB or IME. The use of a DSM-MVR template could be voluntary, however, but the existence of an example template may be useful to project developers, VVBs, and IMEs.

Project Personnel Response: We have provided a new appendix (Appendix 4) that contains a template for the DSM-MVR in response to OBS 1.

Auditor Response: Thank you.

NIR 2 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Sections 2.1 and 5.1

Finding: Section 2.1 states: "In Use Case 2, DSM is used to directly quantify SOC stocks and stock changes. DSM model validation is required at the start of the project and at least once every 5 years. When verification is sought between model validation events, the DSM model must be recalibrated subject to sampling and other requirements described in Section 5.1.6."

Section 5.1 states: "The initial (t0) model validation and associated DSM-MVR is reviewed by an IME at project validation or at the first verification."

Given the possibility projects may seek methodology deviations in the future, the audit team inquires whether there is any situation in which a project could feasibility adopt Use Case 2 for a monitoring period after validation and after the first verification. This may be more feasible for VM0042 projects adopting Quantitative Approach 2, but any feedback from the developer over why Use Case 2 cannot be used after project start in any case is welcome.

Project Personnel Response: We discussed NIR 2 with Doug Baldwin on June 18, 2025. We agree that projects should be permitted to adopt Use Case 2 after validation and after the first verification. We note the distinction between project validation and model validation. These concepts, though both using the term “validation” have different meanings in CN0137. As explained by Doug Baldwin, the original question assumed that a project had been validated (project validation) for use under current QA2 (measure and re-measure), and that the project may then wish to adopt DSM, also under QA2. We agree that such an adoption should be permitted.

Auditor Response: Thank you for the clarification. No further questions, and this finding can be considered closed.

OBS 3 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Appendix 6

Finding: Appendix 6 states after a description of a term in equation 5 of the Tool involving 2*rho: "= 0.0044 (which assumes that rho in Equation 5 = 0.5)".

In that equation, rho would actually be 0.25 to align with the text.

Project Personnel Response: We have corrected this typographical error in Appendix 6.

Auditor Response: Confirmed. Thank you.

NIR 4 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Section 5.1

Finding: Equation 2 shows a calculation of R2. Please note that if this equation was directly used with data from Appendix 6 that it would be greater than 1 (at least according to assumptions held by this auditor). Some additional context about Equation 2 may be required to prevent inaccurate application of this equation. The squared Pearson correlation between observed and predicted could be a start.

Project Personnel Response: The calculation of R^2 presented in Equation 2 differs from the square of the Pearson correlation in some situations. When the model is an ordinary linear regression, then $R^2 = r^2$. The quantity of R^2 (but not r^2) can be < 0. Neither R^2 nor r^2 can be > 1.

The difference between these two quantities is that one (r^2) measures the square of the linear

correlation coefficient. The other (R^2) is the amount of variance explained. These two quantities happen to be the same when the model being used is an ordinary linear regression, but they are not the same for other models, including non-linear regression and the types of machine-learning models typically used with DSM. Thus, we used R^2 because it is a more general expression of the quantity needed by CN0137, which is the amount of variance explained.

The auditor noted that the value for R^2 in Appendix 6 is > 1. However, we suspect that the auditor has made a mistake. We have modified the R code provided by the auditor to compute the value of R^2. In this case it is negative, so we suspect that the auditor forgot that the calculation is 1 – SSE/TSS (i.e. that the auditor neglected the subtraction). Please see lines 559 – 565 in the modified Rmd file provided by the auditor, which contains code showing that R^2 is negative. If the auditor believes that we have misunderstood, please provide an example in code showing that R^2 is > 1 so that we can address the issue.

Auditor Response: Indeed, there was a mistake, where the auditor forgot to include '1 –' in front of SSE/TSS. Given the premise of this was based on that mistake, and that the developer and this auditor confirmed our mutual understanding of Equation 2 over email, this finding can now be considered closed. There are no further questions over the decision to use Equation 2 as part of the Tool's model validation assessment.

NCR 5 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Section 5.5 and Appendix 6

Finding: Section 5.5 of the Tool states: "The DSM-MVR must include a plot of the selected variogram and several candidate alternatives, and must include numerical values of model selection criteria, where used."

Appendix 6 features a mock selection of 3 variogram models using the SSE statistic as a selection criteria. The R code is slightly off when calculating SSE, but the outcome is the same (spherical model is most accurate in this case).

Project Personnel Response: We thank the reviewer for pointing out this typographical error. The

issue was a misplaced parenthesis. We have corrected the typo in the attached version of Appendix 6.

Auditor Response: Confirmed. Thank you.

NCR 6 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Appendix 6

Finding: If this were a real audit on the predictions and observed SOC stock, then the underlying model would be rejected, given an R2 = 0, but it is understood that the developer chose a constant 'm(s)' (in the parlance of Section 3.1 of Wadoux and Heuvelink, 2023).

Project Personnel Response: The auditor is correct. The purpose of Appendix 6 is to demonstrate how to implement the calculations in the tool using a data simulation. This version of the simulation assumes spatially structured SOC stock with spatially structured Gaussian random error. Because the error in this case is random in the absence of a trend, the R^2 is close to 0. In applications of DSM under the tool, a trend is apparent between observed and predicted values and R^2 is > 0. For example, in a recent example developed by Perennial that is currently under peer review, R^2 was 0.487 at the physical-sample level and 0.811 at the field level.

Auditor Response: Thank you for the confirmation and for citing another example. The auditor has no further questions. Consider this finding closed.

OBS 7 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Appendix 6

Finding: The Beta parameter could be adjusted from a constant '54' to a trend of another simulated field in Appendix 6, but it is unclear how much further that would complicate the example. It may be helpful to at least explain how the Beta parameter functions when simulating SOC in Appendix 6 (II. Geostatistical simulation of SOC).

Project Personnel Response: We have in Appendix 6 that beta can be modified to produce fields with different means. We selected a single value for beta in Appendix 6 for the purpose of illustration, and to avoid unnecessarily complexity when demonstrating the calculations in the tool.

Auditor Response: Understood. The uncertainty calculation is the focus of Appendix 6, and the Appendix demonstrates the calculation process effectively. The auditor recognizes the point that adding complexity to 'beta' may take away from the purpose of demonstrating the uncertainty calculation process.

OBS 8 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Appendix 6

Finding: Appendix 6's final section shows how to calculate the uncertainty deduction for VM0042. It may also be helpful to add another section relevant to VM0032's uncertainty deduction, but it is not clear to the assessor as to how much further this would complicate the example.

Project Personnel Response: We have added Major Section 7 to Appendix 6 showing how to compute the uncertainty deduction under VM0032. We ask the auditor to review this section to ensure that our interpretation of alignment between the uncertainty deduction in VM0032 and the quantities in CN0137 is correct. We interpret the standard error calculated using Monte Carlo procedures in VM0032 as equivalent to the square root of the variance of the project mean computed using the methods of Wadoux and Heuvelink (2023) described in the tool and in Appendix 6.

Auditor Response: Thank you for adding Section 7 to Appendix 6. Auditor has no further questions.

NIR 9 Dated 18 Jun 2025

Document Reference: CN0137 (Draft) Section 5.5

Finding: Section 5.5 states: "The DSM-MVR must include a plot of the selected variogram and several candidate alternatives, and must include numerical values of model selection criteria, where used. Nested variogram models are permitted, where different functions are used to estimate the spatial autocorrelation of standardized prediction errors at different lag distances. Nested variograms may be geographically stratified, such that short-distance lags are handled differently in different parts of the project area."

While it is likely that there will be weak or stronger spatial structure in variograms that may be modelled with a semi-variogram, it may also be possible that there is no discernible spatial structure. While a competent IME could make a call on how to deal with the situation, the audit team would like some feedback from the developer on whether there are any downstream effects on uncertainty equations that would negatively impact a project's crediting if a nugget model is chosen as the best representation of the semivariance (assuming no sample or other data-related problems with the empirical semivariogram itself).

Project Personnel Response: A variogram model without spatial structure will result in a smaller estimate of the variance of the mean emissions removal than a model with spatial structure, all else equal. This can be seen in Equation 10 of CN0137, which computes a covariance as a product of variances and the correlation of model prediction errors. A variogram model with no spatial structure will result in values of the correlation that are 0, and hence a small estimate of the covariance. It is important to note that a nugget-only model is not necessarily incorrect, but that it is the responsibility of the IME to judge whether the variogram has been properly estimated (i.e. whether a nugget-only model should be accepted or not). For example, a project proponent claiming a nugget-only model based on a small sample that barely meets the thresholds in CN0137 should be treated with suspicion (which is why CN0137 explicitly recognizes the importance of sampling within the 0 – 500 m range and 50 point-pair minimums within bins).

Auditor Response: The thorough response is appreciated. No further questions, and this finding can be considered closed.