Model Validation & Verification Guidance

For Soil Enrichment Projects

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1 Introduction

A model must show a lack of bias or conservative bias when being used to estimate soil organic carbon (SOC) stock change and, if applicable to the project, flux change of N_2O and CH_4, to quantify soil enrichment projects. Model validation must be specific to the model being used in the project, as well as how the model is being used to make project quantifications (i.e., in what cropping system and geographic location, for what types of agricultural practices, etc.). Model validation must also make appropriate use of published experimental datasets to compare modeled predictions to real-world change. To facilitate this process, the steps laid out in Section 2 must be followed to evaluate model bias and demonstrate meeting model validation requirements.

A discussion regarding verification requirements for the proper implementation of this biogeochemical modelling guidance can be found in Section 3 of this document, as well as Section 8.3.3.1 of the Soil Enrichment Protocol (SEP).

All stakeholders making use of this guidance should contact the Reserve to ensure they are using the most up to date version of this guidance. Project developers and verifiers must use the version of this document that is in place at the commencement of the reporting period in question. In the cases where multiple reporting periods are being verified at once, project developers and verifiers should seek Reserve guidance and approval as to which version of this guidance should be applied to which reporting period.

2 Model Validation

2.1 Declare Practice Categories for the Project

Practices are those which result in one or more changes to the following categories.

- *Fertilizer (organic or inorganic) application*
  - Fertilizer add-on (non-rice)
  - Fertilizer add-on (rice)
  - Fertilizer amount (non-rice)
  - Fertilizer amount (rice)
  - Fertilizer application
  - Fertilizer precision/timing
  - Inorganic fertilizer type
  - Adjust soil pH (e.g., liming)
  - Organic fertilizer composition/CN ratio
  - Organic fertilizer type
- *Water management/irrigation*
  - Flood management (rice)
  - Flooding drydowns (rice)
  - Irrigation amount
- *Tillage and/or residue management*
  - Residue management (non-rice)
  - Residue management (rice)
  - Tillage frequency
  - Tillage inversion

    - Tillage depth
    - Tillage type
- *Crop planting and harvesting (e.g., crop rotations and cover crops)*
    - Cover crop legume
    - Cover crop seasonal
    - Crop rotation
    - Fallow period
- *Grazing practices*
    - Enteric fermentation
    - Grazing
    - Grazing forages

A project developer must declare all categories for which adopted practice changes will be quantified for credits.

2.2 Define the Project Domain

The project developer must declare unique crop types, as well as soil textural classes, and climate zones across all practice categories declared in Step 1.

2.2.1 Identify Unique Crop Types Bins

The full list of crop types to be included in the project must be declared. Crop types can be grouped into bins across crops sharing unique combinations of the following attributes:

- N fixation (Y/N),
- annual/perennial (A/P) (defined in accordance with the NRCS Conservation Compliance categorization of crops[1]),
- photosynthetic pathway (C3/C4/CAM),
- tree/shrub/herbaceous (trees and shrubs have woody plant growth, versus herbaceous species that do not grow woody plant material),
- flooded/not flooded

2.2.2 Soil Textural Classes

For each practice category, the full list of NRCS soil textural classes encompassed in the project domain must be declared, noting the textural classes within the project domain with the highest and lowest clay content. Soil textural classes in order of least to greatest clay content are as follows:

1. sand
2. loamy sand
3. sandy loam
4. loam
5. silt loam
6. silt
7. sandy clay loam
8. clay loam
9. silty clay loam
10. sandy clay

[1] Resource can be found here: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/farmbill/?cid=stelprdb1262733

11. silty clay
12. clay

2.2.3 Climate Zones

For each practice category, the full list of Climate Zones encompassed in the project domain must be declared, following the climate zone definitions given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2.3 Gather Validation Data that meet the Following Requirements

Requirement 1: Validation datasets for each declared practice category from Step 1 must include a minimum number of measurements (declared in Requirements 2 and 3) for each modeled quantity, where the modeled quantity is the change in the flux of emissions to the atmosphere for SOC, N_2O, and/or CH_4 that results from adopting a practice. Validation data for N_2O and CH_4 must be seasonal or annual in duration.

- Measured datasets must be drawn from peer-reviewed and published experimental datasets with measurements of SOC stock change (and annual/seasonal measures of N_2O and CH_4 change if applicable) with adoption of practices within a category. All dataset sources must be reported. The same measurement dataset sources can be used for model validation across practice categories, if applicable to more than 1 category.
- In the case SOC change with the adoption of a practice, priority is to be given to sources reporting repeat measurement through time across at least a 5-year interim. Alternatively, measures of paired fields using space-for-time substitution approximating at least a 5-year interim with the adoption of a practice are acceptable, if sources with repeat measurements are not available.
- In the case of annual/season changes in N_2O and CH_4 flux, priority is to be given to first paired chamber and eddy covariance tower measurements, then eddy covariance tower measurements alone, then chamber measurements alone.
- **Or** datasets could be drawn from a benchmark database maintained by a 3rd party, approved by the Global Soils Partnership (or comparable). The use of datasets from a benchmark database should include full citation of the database as well as a description of how datasets were extracted.
- While minimum numbers of measurements are required, the project proponent should be comprehensive in using available datasets that meet the above criteria. If appropriate datasets are found to be excluded, they should be added.

Requirement 2: A practice category is validated at a sample location if there are at minimum 10 measurements each of SOC change and annual/seasonal N_2O and CH_4 flux change (if applicable) with the adoption of practices within that category, as long as the measured data meet the above criteria. The measurements must, in total, cover the soil textural class, crop type, and climate zone relevant to that location.

Requirement 3: A practice category is validated for use across the entire Project Domain if there are a minimum of 30 measurements each of SOC change and annual/seasonal N_2O and CH_4 flux change (if applicable) with the adoption of practices within that category, which in total cover:

- the highest and lowest clay-content soil textural class within the project domain, as well as at least 1 other soil texture class in between these classes;
- all IPCC Climate Zones included in the project domain;
- all crop types included in the project domain where that practice is being adopted.

2.4 Use Model Performance Criteria to Demonstrate Lack of Bias or Conservative Bias for Each Eligible Practice

For each practice category declared in Step 1, the model must be shown to lack bias in estimating the effect of the practice change on emissions reduction in SOC, N_2O, or CH_4 pools, across the project domain defined in Step 2, using measured data that meet the requirements of Step 3. This is done using the calculation of the average relative error, or *ARE* (FAO, 2019; Yang et al., 2014), of measured data versus model prediction. All peer-reviewed and/or published data points meeting the requirements listed above are to be aggregated and used to calculate *ARE*:

$$\boldsymbol{ARE} = \frac{\sum_{i=1}^{n}(\boldsymbol{P_i} - \boldsymbol{O_i})}{\boldsymbol{n} \times \bar{\boldsymbol{O}}}$$

Where,			Units
P_i	=	Predicted (modeled) value of change in SOC, N_2O, or CH_4 with the practice	
O_i	=	Observed value of change in SOC, N_2O, or CH_4 with the practice	
n	=	Number of measured change value pairs for the practice	
$\bar{O}$	=	Average of the observed change value	

ARE indicates the average tendency of the modeled estimates to be larger or smaller than their observed counterparts (Moriasi et al., 2007). An unbiased model will have *ARE* = 0.0. Positive values indicate model overestimation bias, meaning that the model overestimates the practice effect and thus the credits earned. A negative value indicates model underestimation bias, or an underestimation of the credits earned. To ensure the model is conservatively biased, *ARE* must be shown to be ≤ 0.0.

3 Verification of Model Usage

Each verification team must include a person or persons who are expert in the particular biogeochemical model used to quantify emission reductions in that reporting period (if any). Guidance is provided in Section 2 for requirements that models must meet, in order to be eligible. Verifiers will be required to confirm the requirements of Section 2 of this document are met.

Expert guidance is needed to ensure the given biogeochemical model is appropriately validated, parameterized, and calibrated each reporting period. If the project employs the use of a third-party expert to undertake validation, parameterization, calibration, and/or running a biogeochemical model in a given reporting period, then there will be no need for the verification team to independently verify such activities have been done appropriately, provided the verification team: confirms that the use of such third-party has been approved by the Reserve, that the party in question has the requisite expertise, that all requisite steps as set out in Section 2 of this document have been followed, and provided the expert provides the verification team with a sensitivity analysis regarding the requisite data inputs for the given model.

In other words, the verifier is simply required to confirm approval from the Reserve, confirm the qualification of the third-party, and confirm the requisite validation steps have been followed, but the verifier does not independently need to run the model themselves to confirm results appear reasonable. The verification team will still be required to confirm the reasonableness of all data input into the given biogeochemical model, following the requirements for baseline modelling in Section 3.4.1.1 of the SEP, and following expert guidance on the sensitivity of the given model to the requisite data inputs.

4 References

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