Review of the Validation Report of DNDC v10.3 According to the Requirements and Guidance for Model Calibration, Validation, Uncertainty, and Verification For Soil Enrichment Projects Version 1.1a

Validation Report Prepared for CAR by Regrow, Dated: July 11, 2022

Reviewer: Brian McConkey, PhD, Viresco Solutions

Summary

The report was for Type2 or Option 2 validation, i.e., generalized validation to demonstrate overall performance of the model without specific project.

All requirements of the Requirements and Guidance for Model Calibration, Validation, Uncertainty, and Verification for Soil Enrichment Projects Version 1.1 a were specifically met or deviations from those requirements were approved.

The DNDC model V10.3 effectively met the bias requirement and the error requirement that 90% of measurements fell with the 90% prediction interval. Therefore, the model is acceptable for application in the following domain:

Land Resource Regions (LRR) of C, E, F, G, H, K, L, M, N, O, and P.

CFGs of C4 annuals, C3 annual herbaceous, C3 annual N-fixing herbaceous, C3 annual shrub, C4 perennial, C4 perennial, C3 perennial, and C3 perennial N fixing.

Practice category (PC) for annual crops of cropping management, inorganic N management, and tillage-residue management for emission sources (ES) of both SOC changes and N2O emission changes. There was sufficient validation to approve validation of the practice category of organic N management for annual crops but Regrow is not seeking approval for application for this practice category. Practice categories for perennial crops were cropping management, inorganic N, and tillage and residue management for SOC change but only cropping management for N2O. **Although Regrow was seeking their approval, the practice categories of N management and tillage-residue management were not approved for DNDC use for N2O emissions for perennial crops since no validation data was included for these practice categories for perennial crops. Further, owing to relatively weak validation data coverage over the approved domain for perennial crops, the strong recommendation is that application of DNDC in the approved domain be limited to projects where the sum of the absolute values of area changes of, and area of practice categories applied to, perennial crops is less than 25% of total project area.**

2 Model Calibration

The report describes that calibration of model parameters failed so the validation of was for the default DNDC parameter sets. Instead, the default parameters for DNDC 10.3 were used. These parameters were developed from decades of work that involved improving the model to better match real-world measurements. The Regrow proponents note that they do not believe that any data used for model validation was used during that development, although they cannot be absolutely certain. However, with certainty, there was no calibration of all model parameters across data used for validation in this report. Therefore, this validation report meets the SEP Validation Guidance V 1.1a principle that the data used for validation was not used for calibration.

2.3 Documentation

Required data:

a) Model version was specified
b) Description of the model validation process
c) Same parameters are for all LRRs
d) Justification for choice of calibration data sets or provision of data sets was not required.
e) Documentation of datasets for calibration was not needed.

There is rigorous archiving of version 10.3 is followed including all parameters. The archive includes the data and version used for this validation report and is available upon request to future Verifiers.

3. Validating and Reporting Model Performance and Uncertainty

3.1 Practice Categories

The practice categories were described, and the data used for validation for each practice category and the LRR included in the data for each practice category.

3.2 Validation Domain

The validation was across the whole domain. This approach to use the whole validation domain was approved by CAR via email of Oct 22, 2021 (Appendix C of the Validation Report). This reviewer agrees with CAR that such validation is sensible given the objectives of validation and the limited availability of high-quality data for validation. Calculation of the PMU is also a problem with granulated validation.

The domain was defined in terms of combinations of PC, CFG, and ES that were validated for included LRR. DNDC was validated for the PCs of tillage and residue management, Inorganic N management, and cropping management such as crop rotations and cover crops. Although a number of the studies used for validation included a practice category organic N management, the proponents chose not to validate DNDC for organic N management since validation data did not cover the at least three LRR. This was not necessary as CAR approved validation across a single domain. **Therefore, based on this validation report, DNDC V10.3 could be considered validated for the practice category of organic N management for the domain.** In appendix B, study-site MTSINVND-NV ND lists “h2o”, presumed to be water management, as a practice category, the DNDC model is not validated for water management based on this validation.

The LRR that were validated were listed (C, E, F, G, H, K, L, M, N, O, and P).

DNDC was validated for CFGs were C4 annuals, C3 annual herbaceous, C3 annual N-fixing herbaceous, C3 annual shrub, C4 perennial, C4 perennial, C3 perennial, and C3 perennial N fixing. All were for non-flooded conditions.

The different growth patterns of perennial than annual crops affect both C and N cycling in agricultural systems. This reviewer considers the validation for perennial crop extremely weak based on the limited validation support. There were only 3 study-sites for SOC and 1 study site for N2O emissions for perennial crops. All PC in the domain were included for SOC for perennial crops in the validation data but only cropping management was available for N2O. The CAR ruling that a single validation across the whole domain is acceptable subject to approval of the validation report reviewer. **This reviewer rules that there is not sufficient validation of DNDC in this validation report for the practice categories of inorganic (or organic) N management or tillage-residue management when applied to perennial crops for N2O emissions.** Important to this decision is that, unlike SOC, there will not be in-project N2O measurements to verify DNDC N2O emission estimates. Thus, the thoroughness of validation of DNDC N2O emission estimates is fundamental to have confidence in those estimates for a project. Without any validation data other than cropping management for N2O, this reviewer cannot approve use of DNDC for PC of N management or tillage-residue management for perennial crops.

To improve the validation for perennial crops, a revised validation report with more validation data for perennial crops. The recommended minimum criteria for a validation report for perennial crop s are that are there be at least 3 LRR and clay content range of 15% across perennial crops for all PC and ES in the validation domain for annual crops and a similar requirement for perennial crops. In this Validation Report, these criteria were met for annual crops but not for perennial crops for the PC x ES.

Alternatively, this reviewer recommends a reduced level of validation for perennial crops but with the limitation that the validated model is only applied to projects where the changes of the amount of and practice categories to the perennial crops are relatively unimportant to the project emission changes. The recommended minimum criteria for reduced validation requirement are 1) that there be at least one study-sites for each PC x ES across perennial crops, and, across perennial crops there be at least 3 LRR and a 15% clay content range and 2) that 90% of the measured values for all validation data for perennial crops for each ES fall within the 90% prediction intervals from this validation report. **This validation report only meets a reduced level of validation data coverage for perennial crops for SOC change and N2O emission due to cropping management. This reviewer recommends for projects using this reduced level of validation data coverage be limited to projects where the sum of absolute values of area changes of, and the area of practice categories applied to, perennial crops are less than 25% of total project area. This means that practice changes involving perennial crops, including conversion to or from perennial crops, are never predominant in a project. However, to be coherent with the CAR ruling of acceptability of validation across whole domain, this restriction of DNDC application to projects based on this Validation Report is only a strong recommendation.**

The soil texture classes, and their clay contents were listed. These were not listed for each combination validated but this was not necessary since the validation was across the entire domain.

3.3 Validation Data

The full description of data requirements to initialize and run the model are provided. The approaches to fill in missing data was also provided.

The method of study-sites and treatment pairs was a useful way to organize the validation data. A link to the data sources was provided rather than a classic citation but the link suffices. Between Table 1, Table 4, and Appendix B, the validation data for each LRR, PC, CFG, soil texture was listed. Additionally, the number of observations (treatment pairs) by ES was listed. All the validation data is stated as peer-reviewed so meets the SEP Validation Guidance requirements.

Several of the required data was not included. These were time period, measurement technique, and depths by study-site for SOC.

The time period would not affect the validation for SOC as invariably it is a multiyear period, so this reviewer sees no strong rationale for documenting the time period for SOC. Appendix G shows that time periods range from 1 to 73 years. The validation thus would be valid for time periods of 5 years or less. The time period is important to N2O since N2O measurements may be limited to only the growing season whereas the SEP Validation Guidance requires the validation is for the entire crediting period that will at least one whole year, thus requires measurements outside of the growing season. Appendix D provides the studies that have measurements for more than 310 days and also notes, in some northerly study-sites, the entire non-frozen period can be less than 310 days. This reviewer is satisfied that the number of studies with sufficiently long N2O measurements is adequate to validated DNDC for the entire year.

The types of measurement techniques allowed for validation were included. This reviewer judged all these techniques as acceptable for purposes of differences within treatment pairs.

The measurement depths varied from 10 to 30 cm across study-sites while the validation was for dSOC was compared with the model estimate to 30 cm. Figure 7 (section 3.5) and Appendix E show that there was no significant effect of measurement depth on the difference between measured and modeled indicating that, for the studies that had <30 cm measurement, the dSOC was accurately covered by modeling SOC change to 30 cm. Therefore, this reviewer is satisfied that the selection of data with their varied depths was acceptable for the validation over this domain.

3.4 Assessment of Bias

The validation report adequately describes the procedures used to derive the PMU. The report provides an example derivations of PMU as required by the SEP Validation Guidance. These were for dry combustion with C analyzer for dSOC and vented soil chamber for N2O – both acceptable and common methods. The validation studies and number of treatment pairs is provided to derive the PMU were provided. A single PMU was provided for each ES consistent with the CAR ruling that validation can be across the whole domain.

The bias was calculated and shown for each study in Appendix G ranked by deviation, meeting the requirements of the SEP Validation Guidance. The validation method used a Bayesian framework to estimate a single delta term that represents model discrepancy, which is an estimate of the deviation of

model estimate from the measured from the validation data. The arithmetic mean bias will include some impact of random variation. In contrast, the delta value does not include the impacts of the random error effects as random effects are included in the sigma variable fit by the Bayesian framework when the delta parameter value was being estimated. Thus, this reviewer judged this delta parameter a better estimate of expected overall bias than the arithmetic mean of study biases requested by the SEP Validation Guidance. Note that the arithmetic mean biases were also presented in section 3.5 Fig 4 and, as expected, were very close in values to the mean delta value but had a marginally larger magnitude. The distribution of delta value provides an alternate representation of the variation of the bias. The estimate of the model bias was well under the PMU for both dSOC and N2O. This was true whether the arithmetic mean bias, or the mean delta value were compared with the PMU.

Hence, all the SEP requirements for assessment of are effectively met.

3.5. Derivation of Model Prediction Uncertainty

All required material was provided: i) graphs of modeled vs. measured are provided that demonstrate that 90% of measurements fall with the 90% prediction intervals (with rounding up 89.8% to 90% for dSOC)., ii) scatterplots of model predictions vs. measurements were provided, and iii) histograms of residuals between predictions and measurements.

The validation method is most consistent with application of the Monte Carlo method of error propagation under SEP Appendix D.2. The validation report meets the requirement of SEP Validation Guidance that the required distributions of the model hyperparameters, delta and sigma, are provided – delta in Figure 2 in Section 3.4 and sigma in Figure 5 in Section 3.5. Other model parameters were constant for this validation and are provided with archived model. Therefore, the requirements to apply SEP Appendix D.2 are met.

3.6 Extension of uncertainty model to the soil enrichment protocol

The request for a deviation from the SEP Appendix D guidance is sound and reflects different but scientifically justifiable assumptions about geospatial nature of removals and emissions from that in SEP Appendix D.

The method outlined for estimating project level uncertainty from fields in the project is consistent with the uncertainty derived from the uncertainty model and so is scientifically sound.

Annex. Review Requests and Regrow Responses during validation Report Review Process

Reviewer Request	Regrow Response
Provide more detail and documentation to define the domain showing the CFG, PC, ES, and LRR for which each validation study site	Documentation was much improved.
Provide justification for using SOC measured to depths less than 30 cm since 30 cm is a minimum requirement of SEP Validation Guidance	Justification was provided showing that depth did not significantly affect the comparison between

	modelled SOC to 30 cm and measured data to depths ranging from 10 to 30 cm.
Document the validation studies that have N2O measurements for the whole effective year.	The studies with measurements covering > 310 days were listed and thereby showed there were a sufficient number to conclude that DNDC is validated for N2O emission over the whole effective year.
Improve the documentation of the calculation of PMU.	Provided.
Clarification that validation data was not used during model development in a way that could be described as calibration.	Clarification provided.
Provide the full list of model parameters for potential use by project verifiers. The purpose was to enable the verifier, if they wished, to verify that those parameters were used in the project using DNDC based on this validation report.	Regrow will maintain a full archive for this validation report including model version, parameters and data used for validation.
Add experimental methods used in example PMU calculation	Provided
Clarify all studies are peer-reviewed.	Provided.
Provide a list of ranked deviations of measured vs modeled for dSOC and N2O	Provided.
Revise some instances of unclear wording.	Done.