N_2O Emission from Cropland: A Procedure for Calibration of the DayCent Model Using an Inverse Modeling Technique

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BACKGROUND

WHAT IS REGULARIZED INVERSION (RI)?

- A statistical parameter estimation approach based on principles of least square minimization, where a best fit is defined by the minimization of the weighted squared differences between measured and simulated observations.
- RI is most commonly addressed by use of the Parameter ESTimation (PEST) code (Doherty, 2010) which is an open source public domain software that allows model independent parameter estimation and uncertainty analysis.
- The PEST code automatically varies model inputs, runs the model and evaluates model outputs to determine the quality of fit.
- To run PEST it needs three types of input files:
  - Template file used to insert estimated parameter values into model input files.
  - Instruction file that instructs PEST how simulated equivalents of observations are read from model output files.
  - A PEST control file (*.pst*) which supplies
  a. Initial values for all parameters included in the calibration process,
  b. Observed values and weights for all members of the calibration dataset,
  c. Regularization constraints, and
  d. Variables that control the operation of all aspects of the RI algorithm implemented by PEST.
- The optimal number of parameters needed for representative model and model complexity is determined by the objectives of the model.

REFERENCES

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- Hunt, R.J., and Tonkin., M., 2007, Are models too simple? Arguments for increased parameterizations: *Ground water*, 45, 254-262.
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INTRODUCTION

DayCent is a biogeochemical model used to simulate the impacts of climate and land use changes. Currently DayCent was used for the annual U.S. inventory of GHG emissions. Although, this model has been applied to a wide range of ecosystems, it is still parameterized through a traditional "trial and error" approach and has not been calibrated using statistical inverse modeling. Lamers, M. et al. (2007) and Hunt R J et al. (2007), among others, suggest that inverse modeling often leads to superior results. The PEST software can be used for DayCent calibration through regularized inversion as well as for evaluating model sensitivity and uncertainty analysis. The inverse modeling approach can improve the model performance, reducing differences between measured data and the model outputs. The use of sensitivity and uncertainty tools can provide valuable insight into the model structure, allowing for determination of the simplest and most realistic parameter field that is compatible with and makes full use of the information available in the data. This insight is valuable for guiding model development and making the best use of models of this type for estimation of GHG emissions.

OBJECTIVE

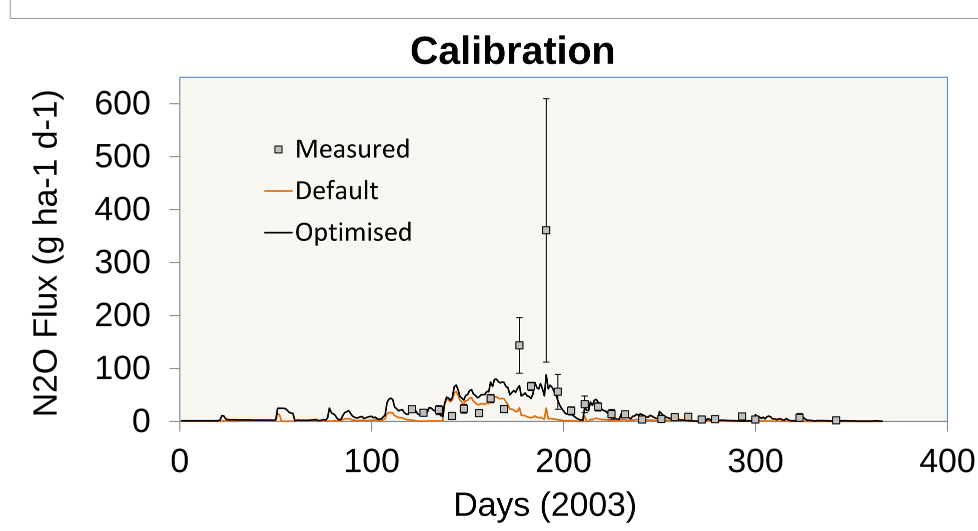
- To establish a procedure for calibration of the DayCent model using PEST – parameter estimation software for universal inverse modeling

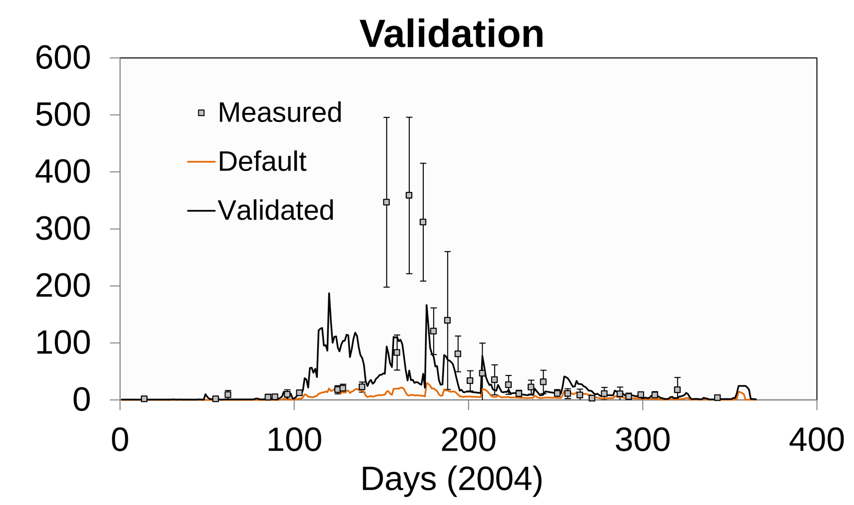
MATERIALS & METHODS

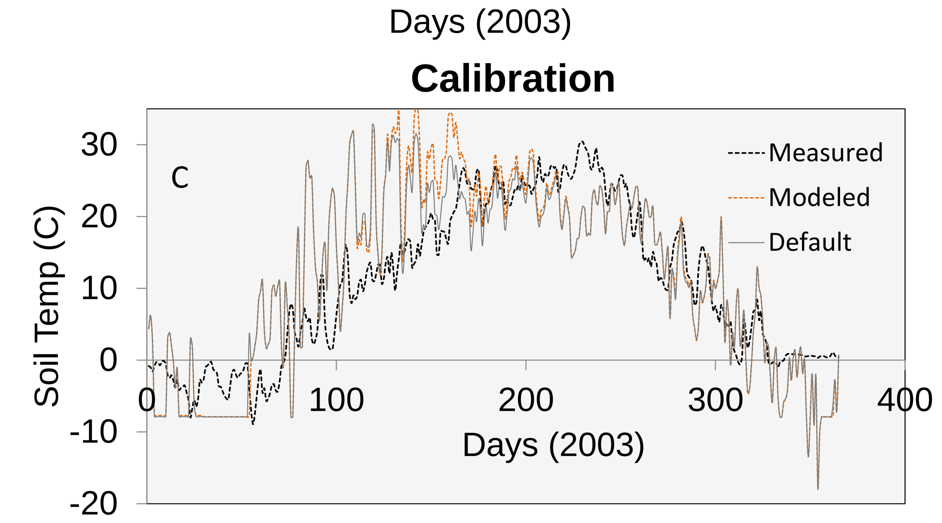
- For this illustration two yr N_2O data (cover crop treatment) was used from the Iowa State University study site.
- 1st yr data was used for calibration purpose while 2nd yr was withheld for validation.
- DayCent model was run using default parameters for the baseline simulation.
- Then PEST was coupled with DayCent for sensitivity analysis using 150 parameters controlling N_2O emissions.
- The most sensitive parameters were selected for the optimization process and ran the PEST iteratively to get the best fit for measured and modeled results.
- The baseline results were compared statistically (*R, BE, RMSE, rRMSE*) with optimized and validated results to see the model improvement.
- The measured soil temperature (STMP) and soil moisture (SM) were also compared with the modeled values to see the model performance.

RESULTS & DISCUSSION

- With the present results, model did not show the improvement as it was expected .
- The N_2O emissions showed reasonable results in calibration year compared to validation year (Fig: A , B: Table 1).
- Model was not able to identify the N_2O peaks occurred through out the year and underestimated both daily and annual fluxes compared to measured values (Measured annual flux : 1st yr = 8.20 kg N_2O-N ha^{-1} yr^{-1},; 2nd yr + 15.50 kg N_2O-N ha^{-1} yr^{-1}).
- As reported from DayCent developer, the model is not performing well for N_2O emissions under cover crop treatment which needs model improvement.
- STMP and SM have not shown any significant improvement (Fig: C, D) in calibration period. Therefore validation results are not shown.
- SM and STMP showed different trends in different part of the yr which is quite different than measured values. This needs further investigation of the model parameters controlling STMP and SM dynamics. STMP found to be very reasonable only during the peak occurring period (mid yr) compared to other part of the yr.
- Better results are expected after correcting the STMP and SM parameters and correcting the effect of cover crop treatment on N_2O.







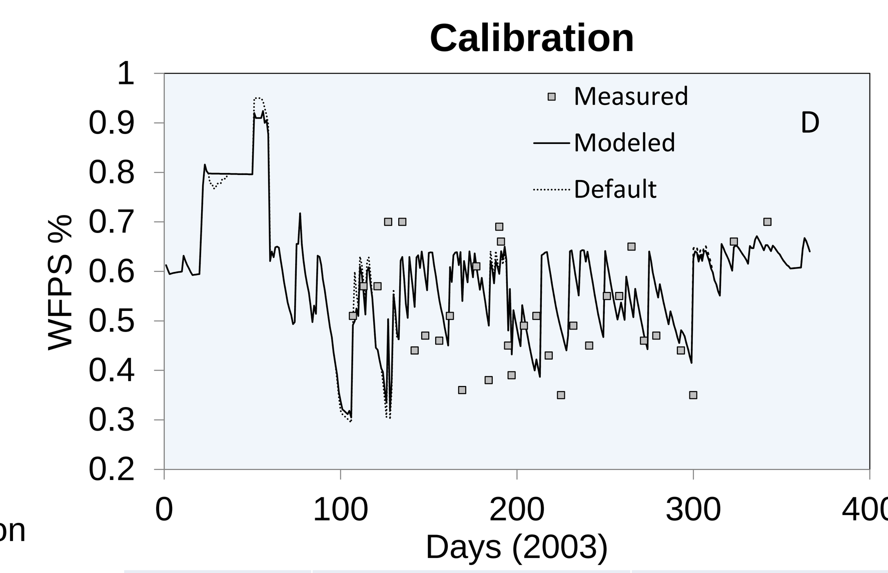


Table 1: Statistics for DayCent – PEST simulations. *R* = Correlation coefficient, *BE* = Biased error, *RMSE* = Root mean square error, *rRMSE* = Relative root mean square error.

	Calibration period		Validation period	
	Default	Calibration	Default	Validation
R	0.23	0.68	0.41	0.54
BE	-35.42	-17.53	-45.79	-22.98
RMSE	92.86	75.07	101.78	85.28
rRMSE	0.93	0.75	0.94	0.77
Annual Flux (kg N2O-N ha-1 yr-1)	4.1	6.02	2.1	8.6

CONCLUSION

Automatic calibration may improve the results significantly after in depth exploration of the model parameters relating to cover crop, soil temperature and soil moisture conditions.

ACKNOWLEDGEMENTS

This work is funded by the US Department of Agriculture (USDA), National Institute of Food and Science (NIFA)

This research is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190 "Cropping Systems Coordinated Agricultural Project (CAP): Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems"
August 2012 | sustainablecorn.org

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