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Modeling the effects of management practices on soil greenhouse gas emissions and nutrient content for a corn-soybean system

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INTRODUCTION

- **Greenhouse gas (GHG) emission monitoring:** Intensification of agricultural practices has increased environmental emissions on a global scale. In United States, agricultural accounts for 75% of nation's N_2O emissions. Global warming potential of N_2O is 265 times that of CO_2[1].
- **Soil carbon:** Agricultural soils make up a major repository of global labile carbon. Depending on management practices, they can be sinks or sources of CO_2.
- **Carbon trading** is one of the market-based approach to lower GHG emissions. The highly reliable measurements provide sufficient confidence to carbon markets.
- Current approach uses national averages, which fail to capture high variability of management practices employed, as a reference when compensating farmers[2].
- **Conventional approach:** Use of field studies to quantify GHG emissions requires expensive equipment and are time-intensive.
- **Modeling approach:** Ecosystem models when combined with observation data can provide more reliable and cost-efficient analysis of net soil carbon and N_2O fluxes at field-and regional scale.
- The DeNitrification DeComposition (DNDC) model is a prominent process-based biogeochemical model with global use[3].

OBJECTIVES

1. Use inverse modeling for calibration and sensitivity analysis of the DNDC model
2. Predict the impact of incorporating winter wheat cover crop into a corn-soybean cropping system on GHG emissions using the DNDC model

METHODS

Study site

- Tile drained, Corn-winter wheat-cover crop rotation with conventional till in Maumee River Watershed[4] (Fig.1)

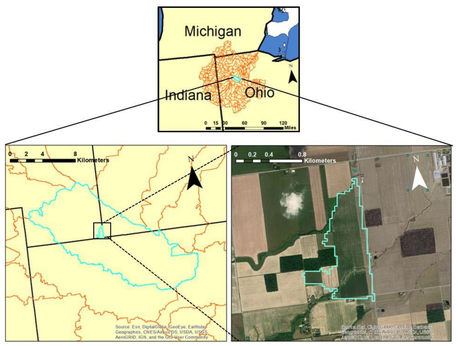

Fig. 1 *Location of study area within sub-basin of Maumee River Watershed.*

Data

- In-situ water and nitrate leaching (daily) and crop yield (annual) for years 2016-2017
- **Soil:** pH, bulk density, clay fraction, etc. from Soil Survey Geographic Database
- **Climate:** Daily max/min temperature and precipitation from National Oceanic and Atmospheric Administration

Calibration framework

- **PEST:** a model-independent, open source software for parameter estimation using inverse modeling [5] was integrated with DNDC (Fig. 2)
  - ✓ Iteratively linearizes non-linear model
  - ✓ Calculates sensitivity matrix of model inputs to outputs
  - ✓ Minimizes sum of weighted square residuals (SWSR) objective function

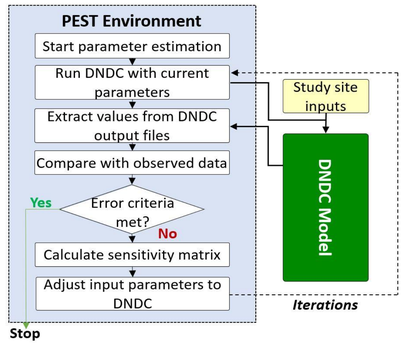

Fig. 2 *Process flow diagram of the PEST-DNDC integrated framework.*

Management scenarios

- **Baseline:**
  - ▶ No cover crop, conventional till (NCC-CT), Corn-soybean rotation, urea ammonium nitrate fertilizer, winter wheat cover crop, 40% residue removal[6]
- **Alternative:**
  - ▶ No cover crop, no till (NCC-NT)
  - ▶ Cover crop, conventional till (CC-CT)
  - ▶ Cover crop, no till (CC-NT)

RESULTS

Sensitivity analysis

Composite parameter sensitivities(Fig.3): Microbial activity, *mai*, percent clay content in topsoil, *cly*, and thermal degree days for corn and wheat, *tdc* and *tdw*, among most sensitive parameters to the model calibration.

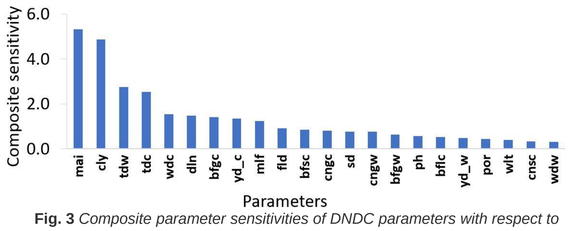

Fig. 3 *Composite parameter sensitivities of DNDC parameters with respect to all output types used in calibration.*

Calibration and Validation

- **SWSR**: decreased 26% and 61% for calibration
- **Coefficient of determination (r^2):** 0.1 and 0.33

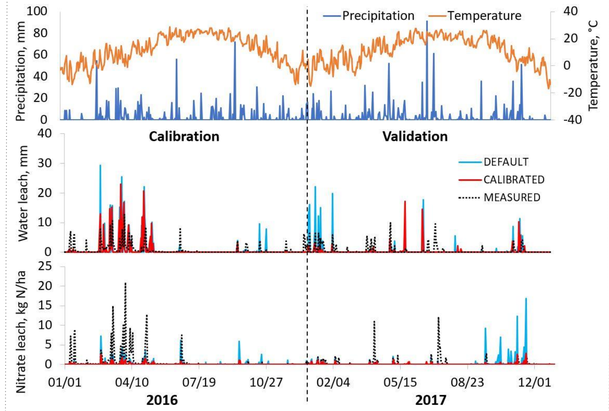

Fig. 4 *Simulated daily water and nitrate leach of calibrated DNDC compared with measured data for calibration and validation years .*

Management scenarios

Nitrous oxide emissions

- N_2O fluxes follow N fertilizer events and precipitation events (Fig. 5)

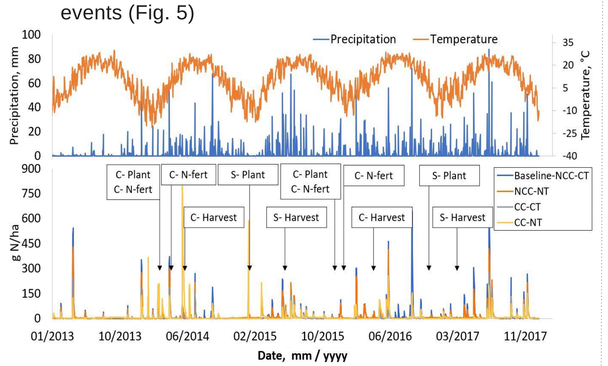

Fig. 5 *Daily nitrous oxide fluxes and climate data with management practices marked for each scenario*

- Lower annual N_2O emissions under CT compared to NT for both scenarios (Fig. 6)

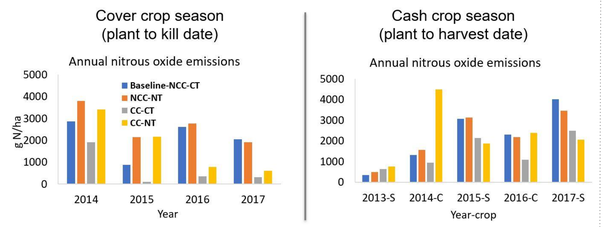

Fig. 6 *Annual and cumulative nitrous oxide emissions over cash crop and cover crop growing seasons for all scenarios.*

Soil carbon

- Management scenarios repeated with historical climate data over past 40 years indicate scenarios incorporating cover crop significantly decreased net soil carbon decline (Fig. 8)

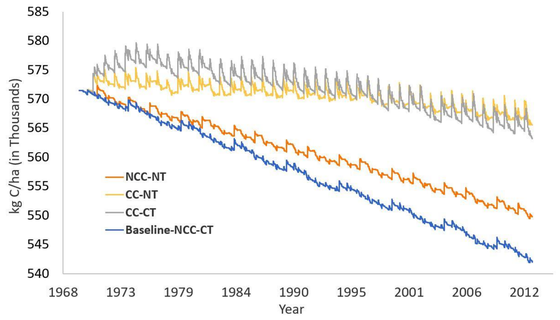

Fig. 7 *Annual and cumulative nitrous oxide emissions over cash crop and cover crop growing seasons for all scenarios.*

CONCLUSIONS AND FUTURE WORK

- **Inverse modeling:** improved DNDC model performance and provided insight into model input-output relationships.
- **N_2O emissions:** DNDC correctly predicted emissions sensitivity to N fertilizer and precipitation events. A possible explanation for more N_2O emissions under NT conditions is that the increase of crop residue at the soil surface in NT compared with CT may retain more moisture, producing more anerobic soil conditions in which microbial activity driven denitrification increases.
- **Soil carbon:** Cover crop with conservation tillage may significantly delay SOC losses, reduce N_2O over long term (>10 years). Longer term tests need to investigate lasting impact of management practices.
- **Future work:** Uncertainty analysis of calibrated model simulations is needed to indicate level of confidence of predicted values.

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