Evaluation of a microbial denitrification model in the Environmental Policy Integrated Climate model

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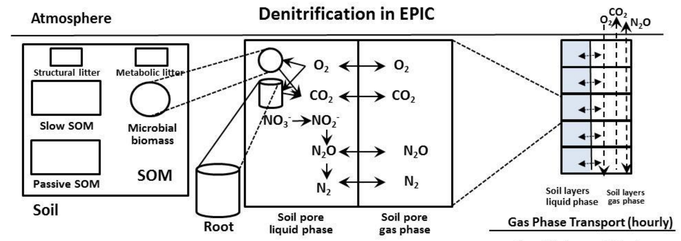
Background & Objective

- Nitrous oxide (N_2O) is a potent greenhouse gas (GHG)
- Agriculture is the main contributor of global N_2O emissions
- Nitrous oxide emissions are strongly influenced by management including fertilization, tillage, and crop rotation
- Land management has a strong effect on N_2O fluxes
- The Environmental Policy Integrated Climate (EPIC) model is a terrestrial ecosystem model that models interactions between crop, soil, climate and management for assessing productivity and environmental impacts (Williams, 1995; Izaurralde et al., 2006)
- A microbial denitrification model was added to EPIC to model N_2O fluxes and their relationship with production system dynamics (Izaurralde et al. 2012)
- There is a need to evaluate the model against field measured data to assess its utility and provide feedback for model improvement

Model Overview



Soil organic matter decomposition (daily)

- Potential C / N decomposition
  - Temperature
  - Water
  - Tillage
- Potential electron supply from microbial respiration
- Actual C / N decomposition based on supply of electron acceptors and of mineral N

Denitrification (hourly)

- Potential electron supply
- Oxygen diffusion to microbial and root surfaces
- Oxygen uptake based on Michaelis - Menten kinetics
- Electrons not accepted by O_2 to denitrification
- Competitive inhibition controls electrons accepted by NO_3^-, NO_2^-, and N_2O
- Feedback of total electrons accepted to decomposition

Gas Phase Transport (hourly)

- Gas diffusion coefficients adjusted for tortuosity
- Partition of gases in gas and liquid phases based on solubility
- Numerical solution of gas transport equation
- Gas concentrations in gas and liquid phases recalculated each hour
- Surface and bottom gas fluxes

Liquid Phase Transport (daily) (dissolved ions and gases)

- Runoff
- Subsurface flow
- Percolation

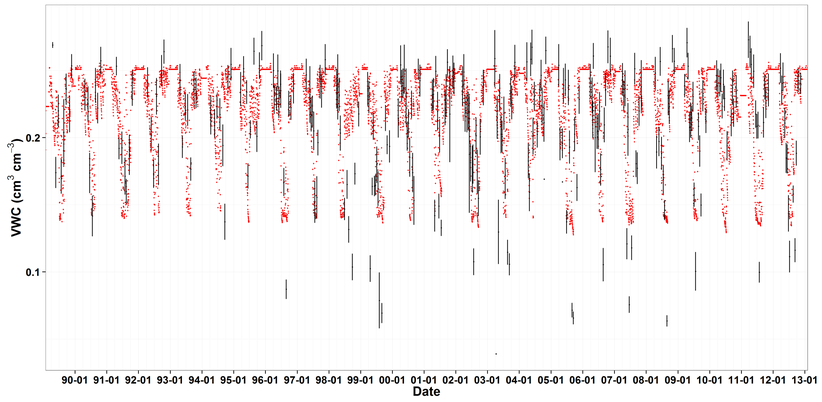
Model Evaluation

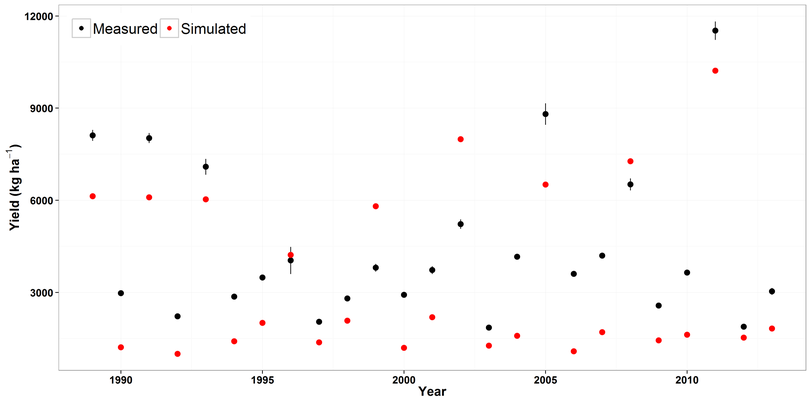
- Evaluated EPIC against measurements from the Main Cropping System Experiment at the Kellogg Biological Station Long-Term Ecological Research Site in Southwestern Michigan (42°24' N, 85°24' W)
  - Managed as a no-till corn-soybean-wheat rotation
  - Replicated as six 1 ha plots
  - Established in 1989
  - Measurements included
    - Crop yield (annual)
    - Soil inorganic nitrogen in top 25 cm (1X or 2X monthly until ground is frozen)
    - Surface N_2O flux (1X or 2X monthly until ground is frozen)
    - Volumetric water content in top 25 cm (VWC; measured with soil nitrogen and N_2O flux samplings)
- Implemented a Particle Swarm Optimization algorithm (Zambrano-Bigiarini & Rojas, 2013) to optimize model parameters related to
  - Soil water balance
  - C/N cycling
  - Crop growth
  - Competitive inhibition by N oxides for electron acceptance

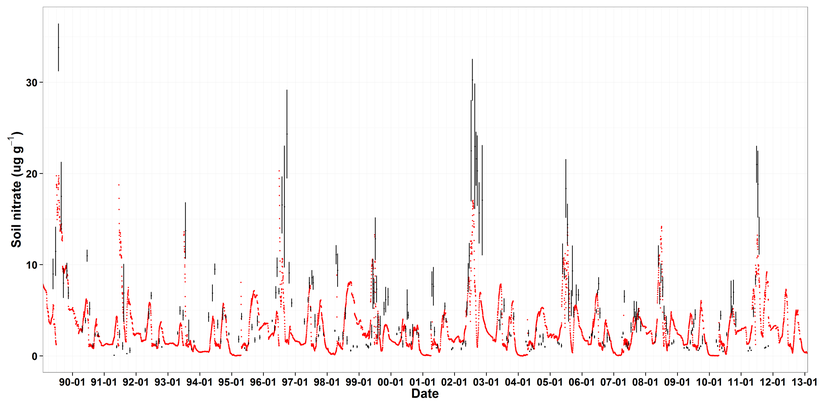
Summary

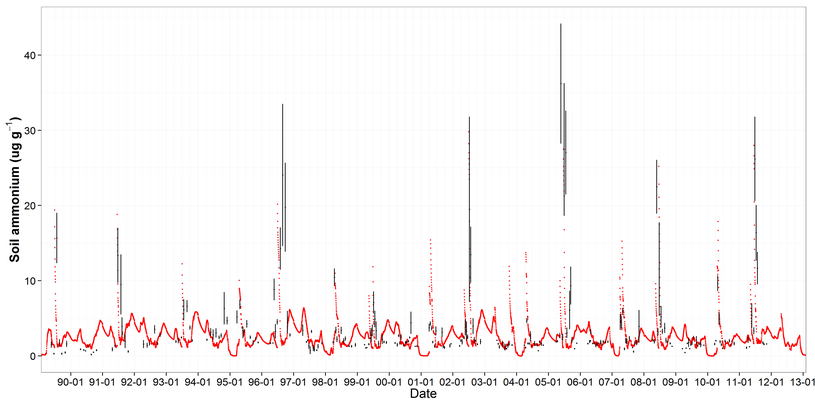
- Dataset provides flux and ancillary measurements to assess core model components in a common crop rotation over a long time period
- Key components of soil water, soil nitrogen and yield are modeled adequately
- Modeling of N_2O follows seasonal trends and peaks, but does not show proper responsiveness to fertilization and wetting/drying trends
- Improvements will consider the impact of O_2 consumption during nitrification and nitrifier denitrification

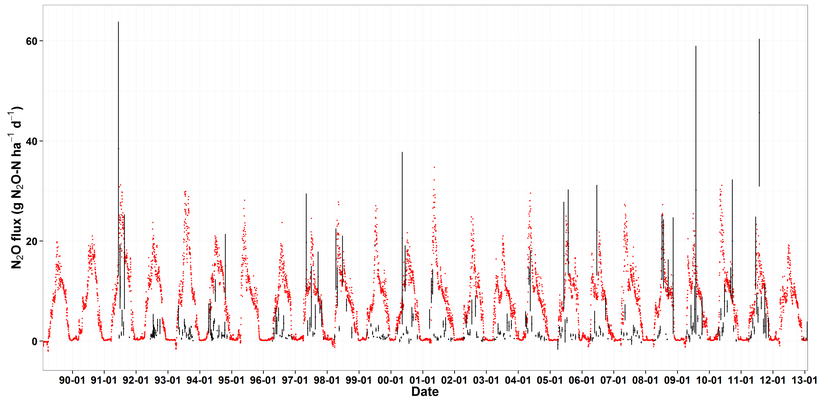
Results











	VWC (cm^3 cm^{-3})	Yield (T ha^{-1})	NO_3-N (ug g^{-1})	NH_3-N (ug g^{-1})	N_2O (g N_2O ha^{-1} d^{-1})
RMSE	0.0370	1.67	4.55	4.37	10.7
R^2	0.363	0.766	0.301	0.198	0.0428

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