Modeling Biogeochemical Processes with APEX

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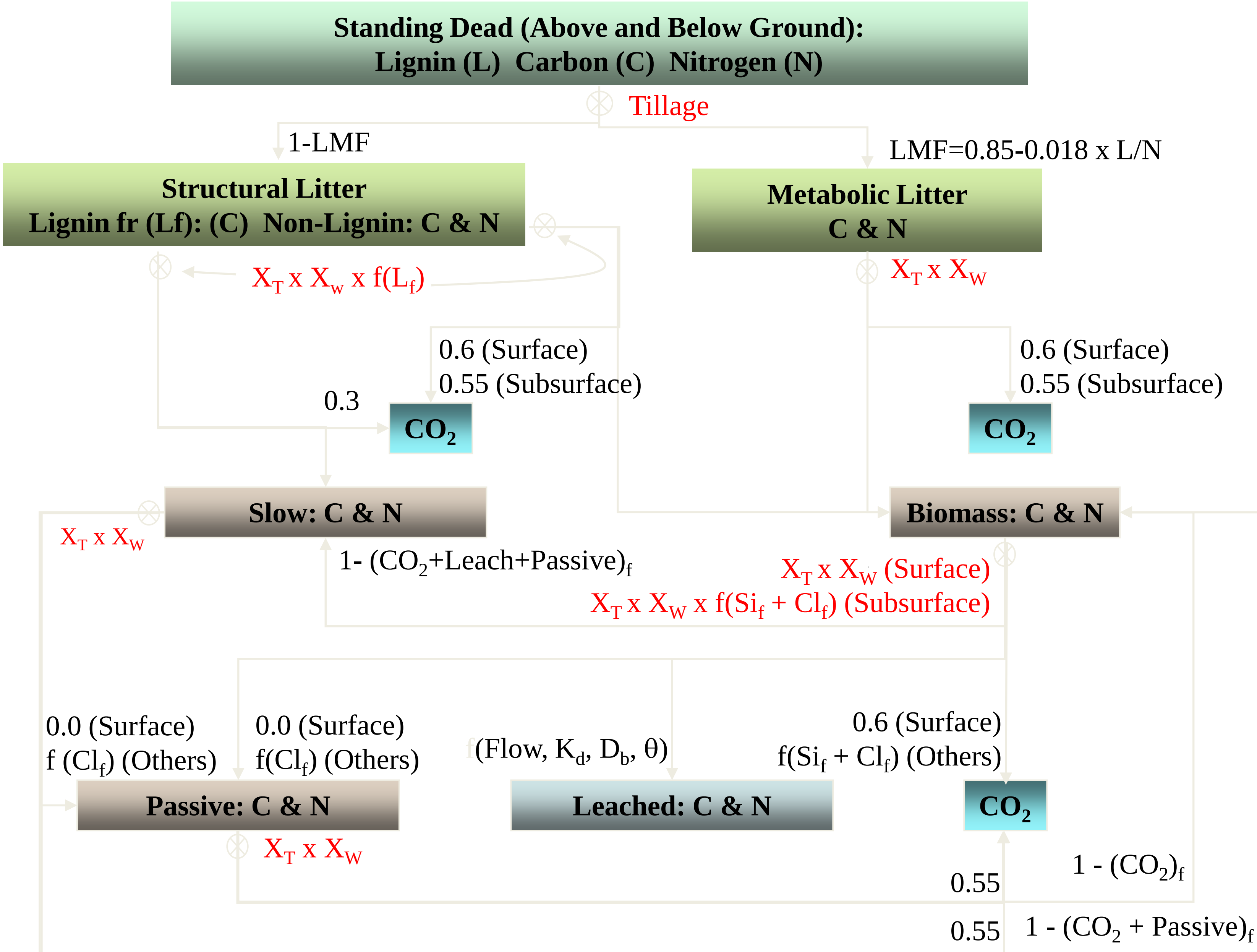
Objectives and Background

- Objectives
  - To review development and testing of coupled carbon-nitrogen cycling processes in EPIC and its incorporation into APEX
  - To present initial comparisons between EPIC and APEX with regards to crop yield and selected biogeochemical processes

- Biogeochemical cycles: the pathway of elements or molecules through biotic and abiotic compartments of Earth
  - ✓ Water
  - ✓ Carbon
  - ✓ Nitrogen
  - ✓ Phosphorus
  - ✓ Sulfur

Altered biogeochemical cycles

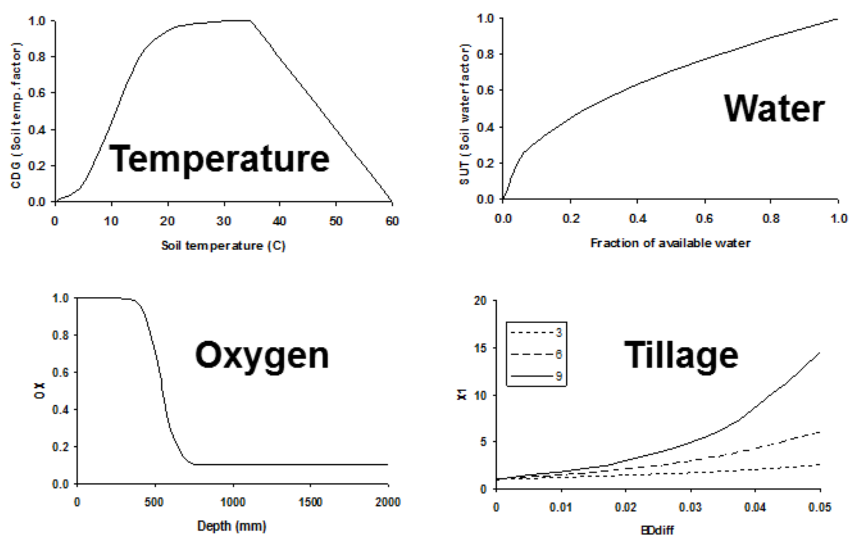


Coupled C & N model in EPIC and APEX

Izaurralde et al. (2006) Ecol. Modell. 192:362-384.

EPIC-based approaches to describe soil organic matter dynamics

Decomposition controls



- Leaching of organic material based on sorption mechanisms and soil water content
- Surface litter fraction in EPIC has a Slow compartment in addition to Metabolic and Structural Litters
- Lignin concentration in EPIC is modeled as a sigmoid function of plant age
- Soil bulk density and soil layer depth change annually as a function of soil organic matter content

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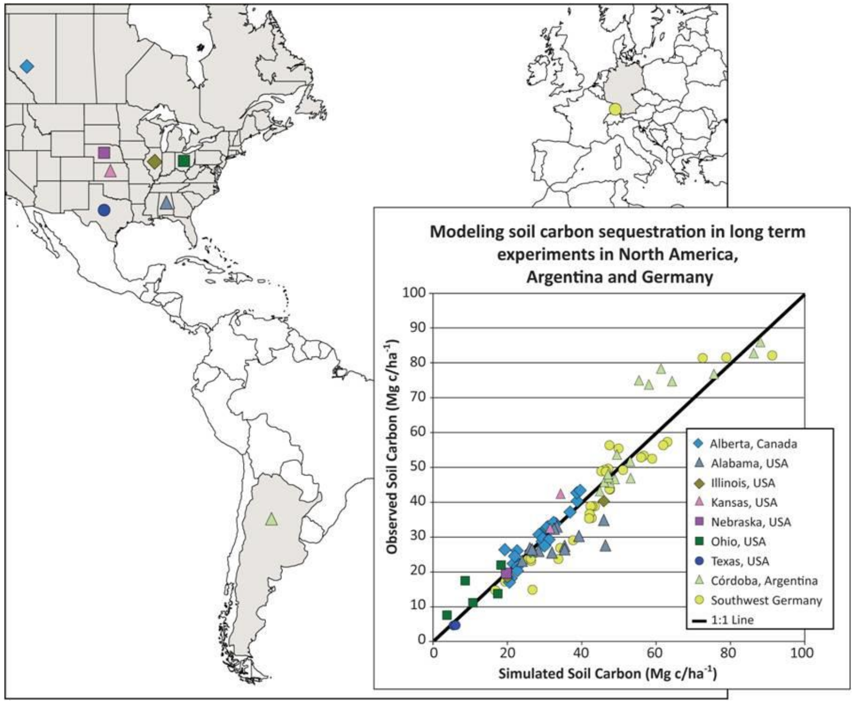
Testing soil C and N modules in EPIC with long-term data

- Numerous long-term experiments worldwide used to test EPIC
  - Crop rotations
  - Tillage
  - N fertilization
  - Landscape effects
  - Erosion / sedimentation
  - Land use change
    - Woody encroachment
    - Prairie restoration
- Most experiments included interactive effects
- Soil C change at depth

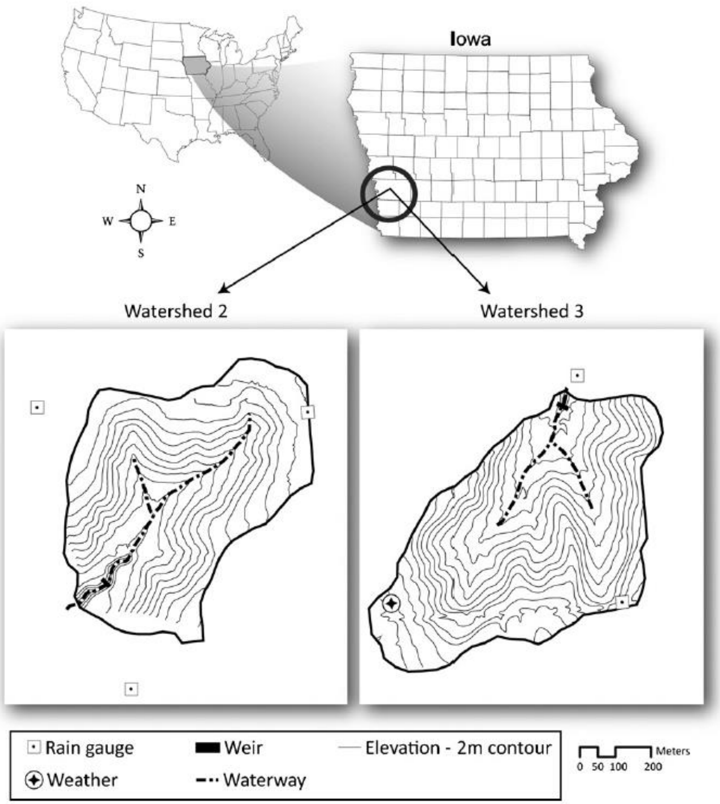


Izaurralde et al. (2012) In: Managing Agricultural Greenhouse Gases, p. 409-429.

Simulating soil management impacts on corn yields, runoff, sediment yield, and soil C with APEX

Wang et al. (2008). Soil Till. Res. 101:78-88.

Deep Loess Res. Stn. Watersheds SW Iowa



Cumulative runoff and sediment yield

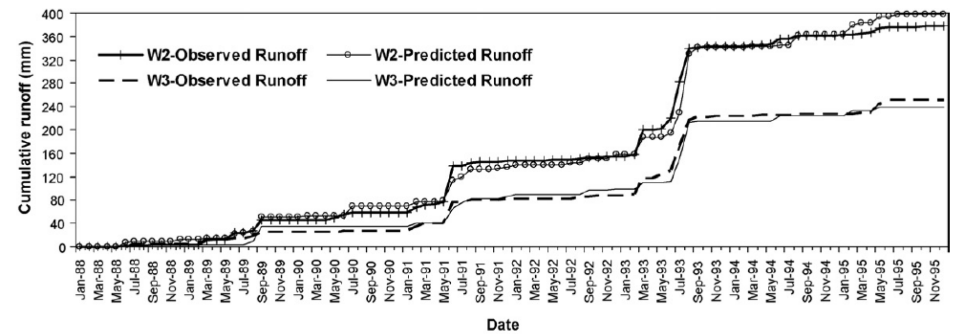
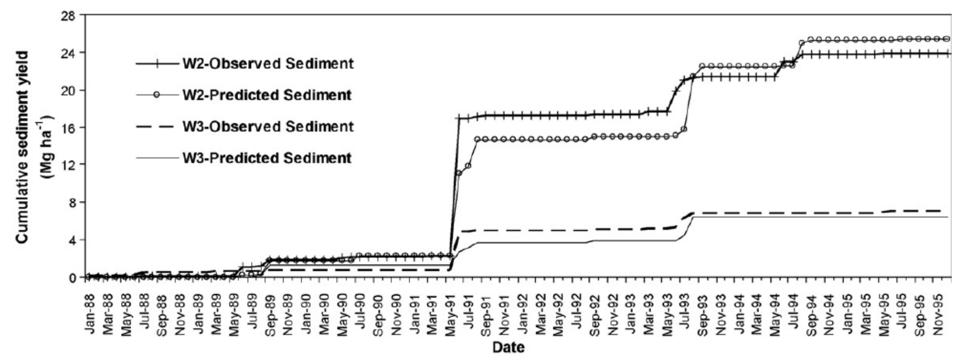


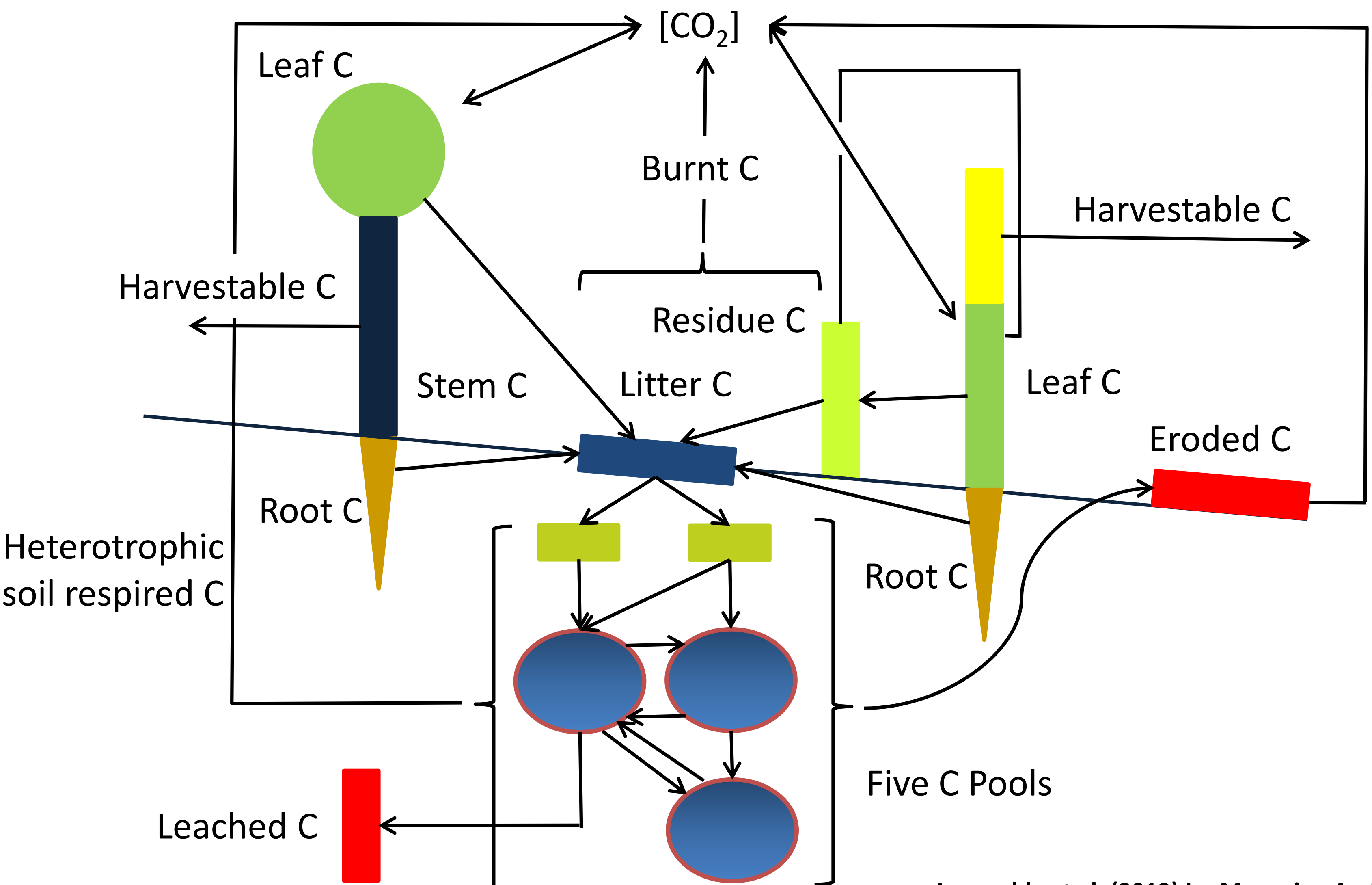
Fig. 5. Predicted verse observed surface runoff cumulated by month for watersheds W2 and W3 for the validation period.



Corn yield and soil organic carbon

	Year	W2			W3		
		Observed (Mg ha^{-1})	Predicted (Mg ha^{-1})	% Error	Observed (Mg ha^{-1})	Predicted (Mg ha^{-1})	% Error
Corn grain yield	1976–1995	7.29	6.93	−4.9	7.59	7.36	−3.0
Soil organic carbon	1994	26.6[a]	29.1	9.2	34.7[a]	36.4	5.0

Representation of Ecosystem Carbon in EPIC



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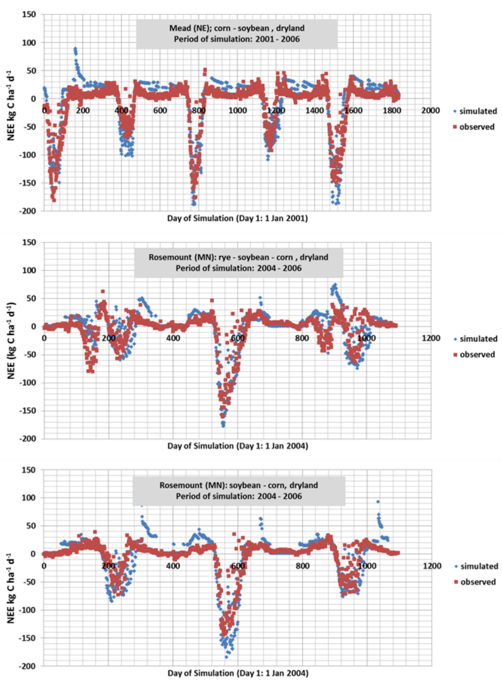
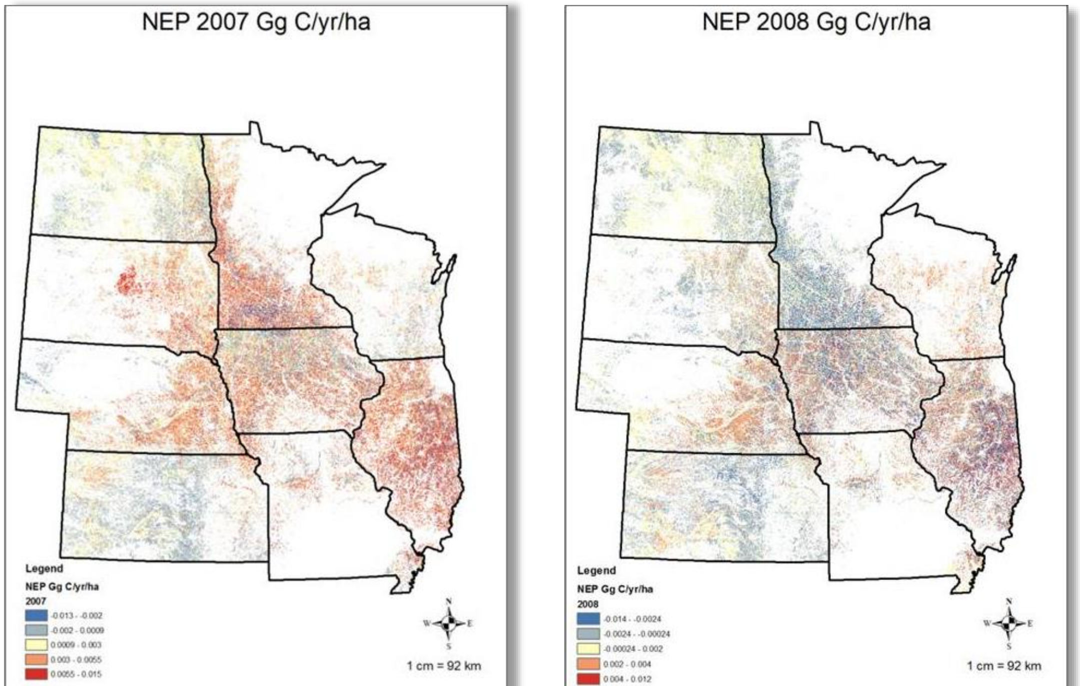
Applying EPIC to study carbon cycling in agricultural systems

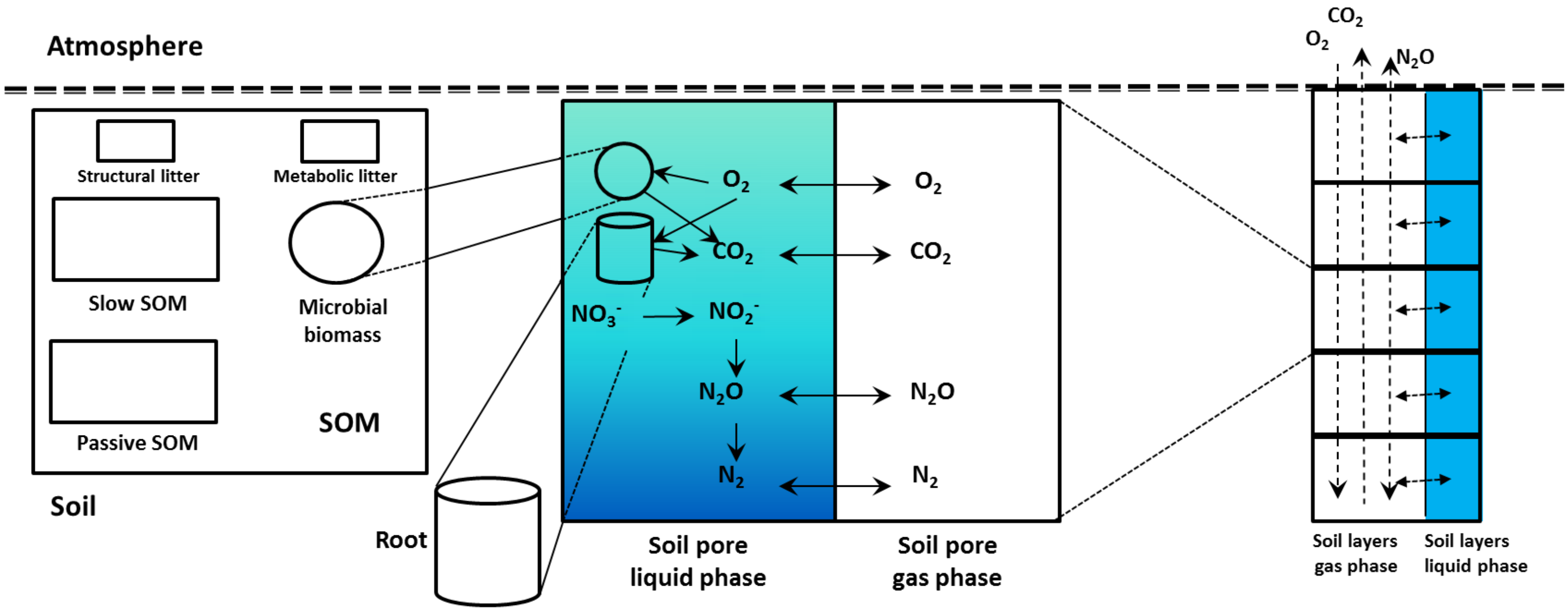
- Developed capability to calculate Net Ecosystem Carbon Balance in EPIC (and now extended to APEX)
  - Vertical C fluxes: NPP, R_h
  - Lateral fluxes: $C_{erosion}$ (POC and DOC), $C_{leaching}$ (DOC),
  - Carbon removals – additions: manure, biochar, harvest, burning
- Carbon emissions due to practices (fertilizer, tillage, pesticides)



Schwalm at al. (2010) J. Geophys. Res. – Biogeosc.



Zhang at al. (2014) Sci. Total Environ.



Soil organic matter decomposition (daily)

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

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 approach to decide electrons accepted by NO_3^-, NO_2^-, and N_2O

Gas Phase Transport (hourly or less)

- Gas diffusion coefficients adjusted for tortuosity
- Initial 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 time step

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

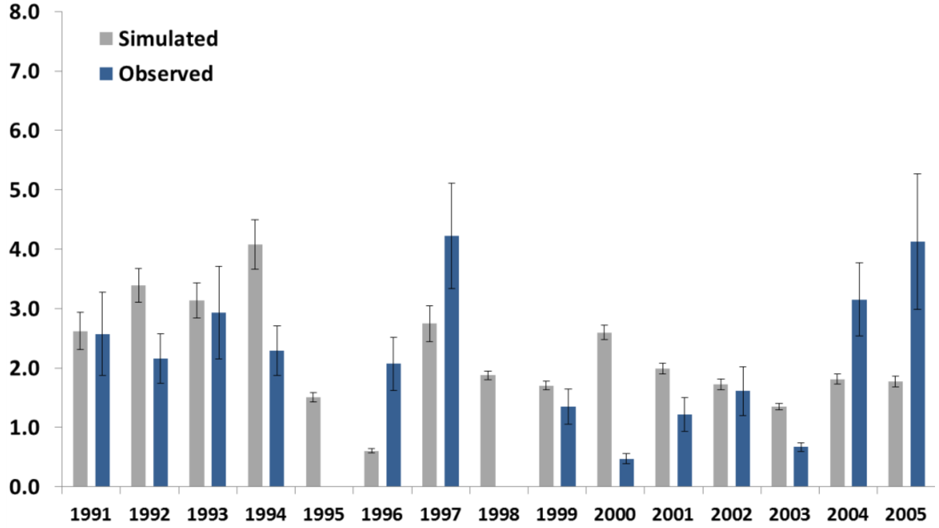
- Runoff
- Subsurface flow
- Percolation

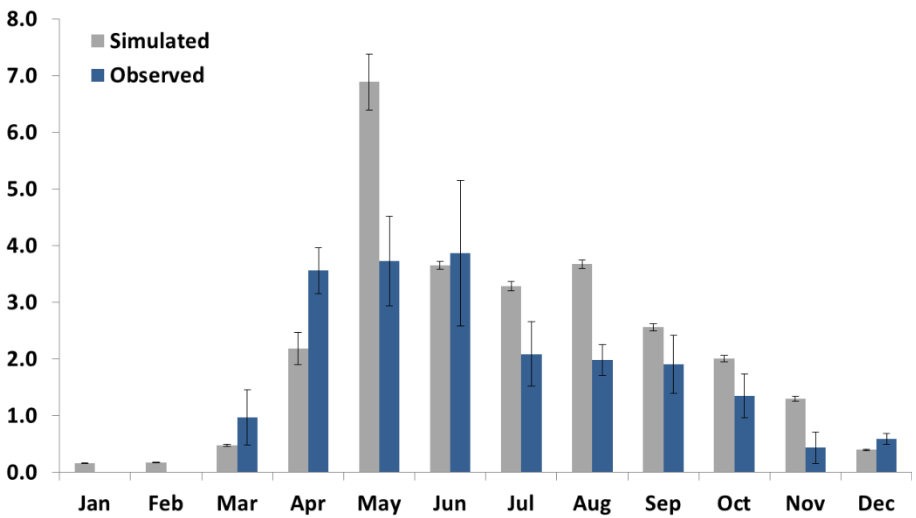
Denitrification model in EPIC and APEX

Izaurralde et al. (2012) In: Managing Agricultural Greenhouse Gases, p. 409-429.

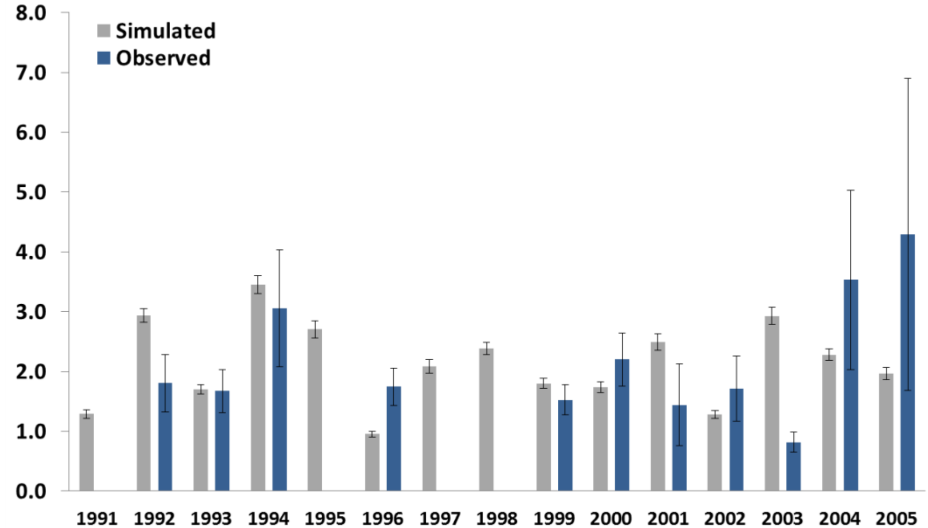
Simulated vs. observed annual and seasonal N_2O flux ($g\ N_2O\text{-}N\ ha^{-1}\ d^{-1}$) in a corn – soybean – wheat rotation at KBS

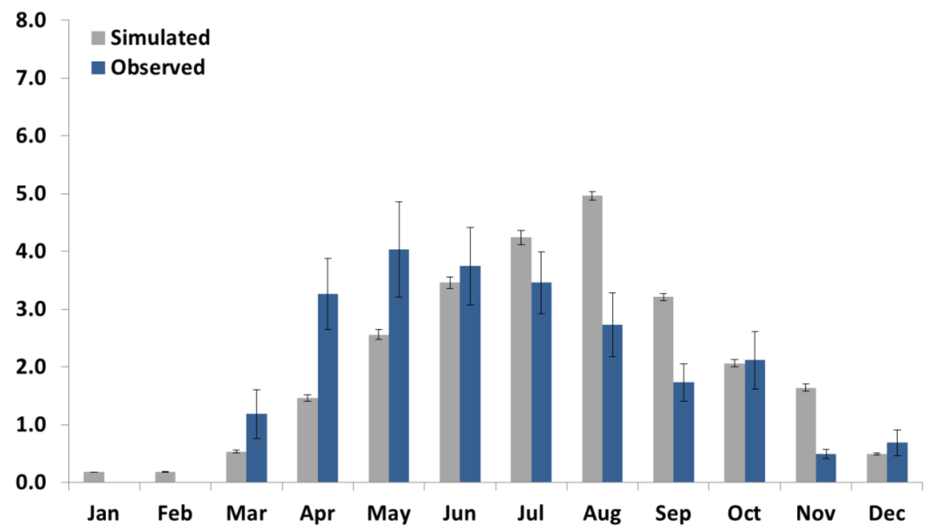
Conventional tillage



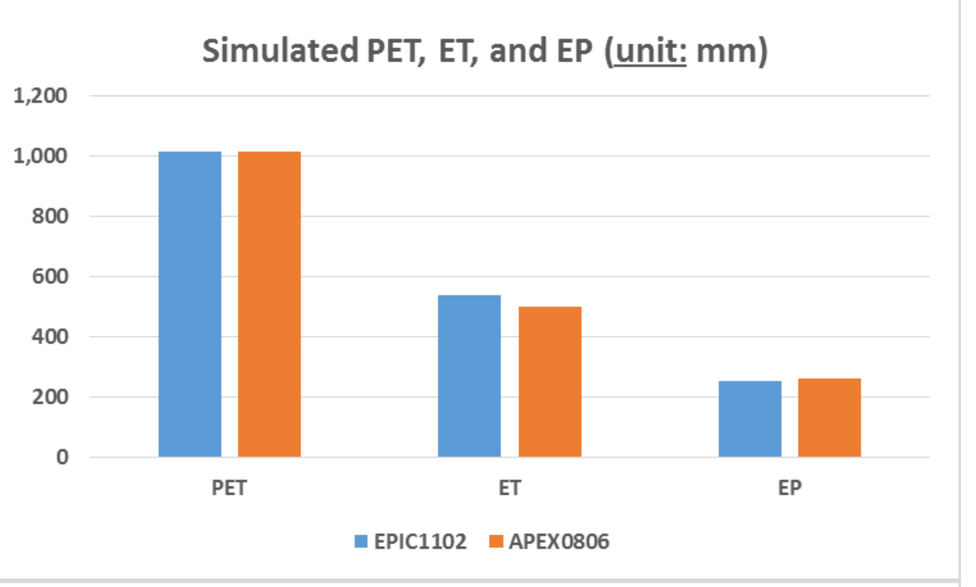


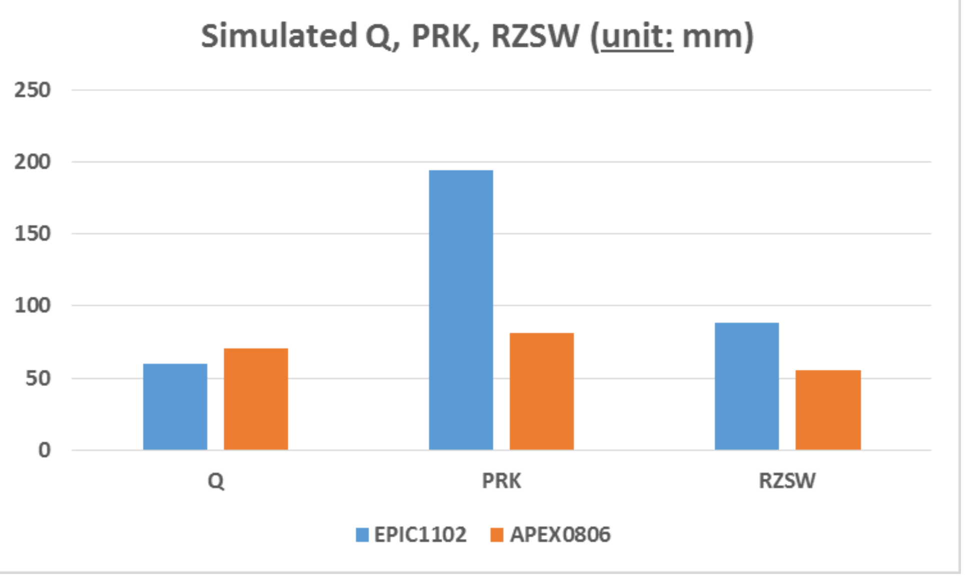
No tillage



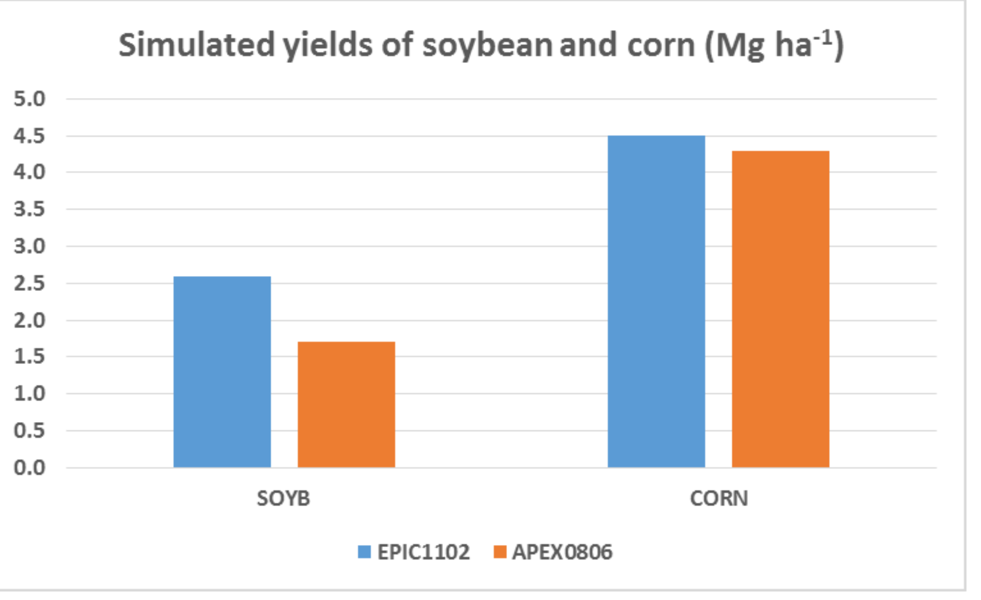


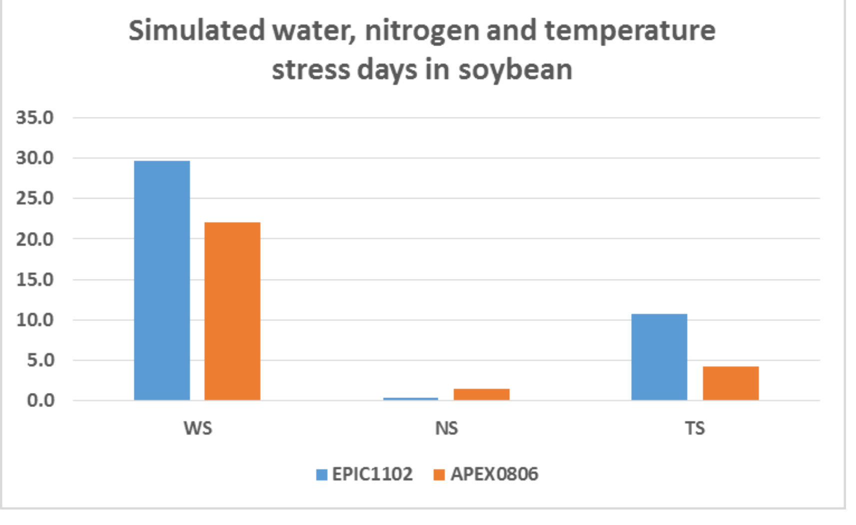
Simulated annual potential evapotranspiration (PET), evapotranspiration (ET), transpiration (EP), runoff (Q), percolation (PRK), and ending root-zone soil water (RZSW); unit: mm

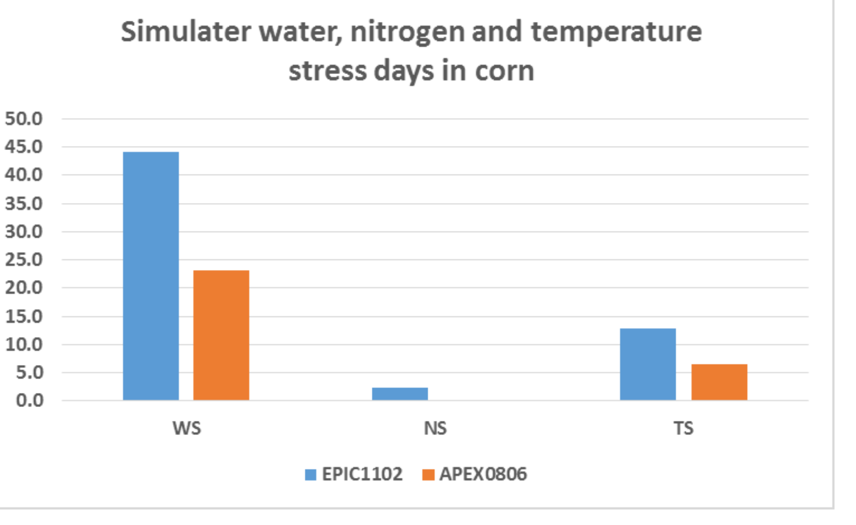




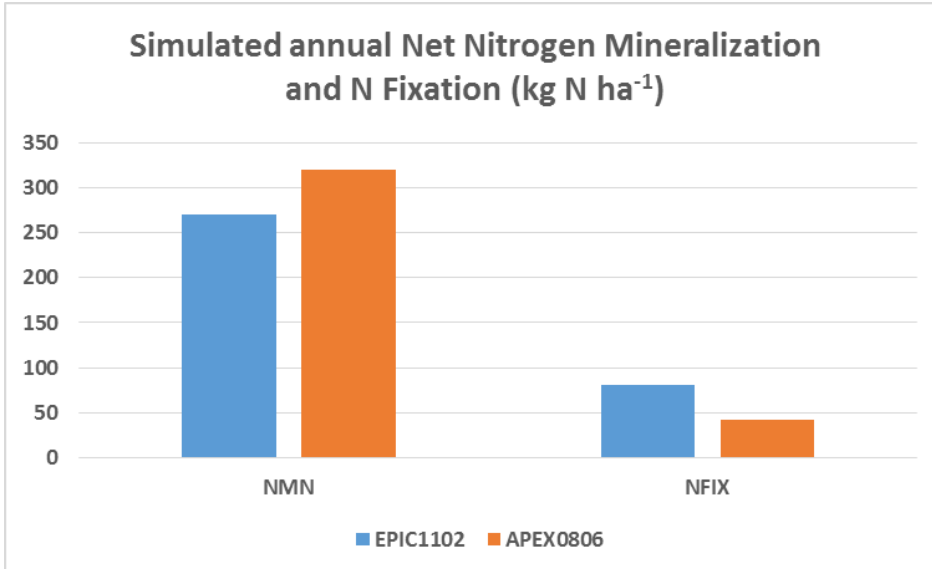
Yield (Mg ha^{-1}) and yield stresses (days) of soybean and corn simulated with EPIC1102 and APEX0806

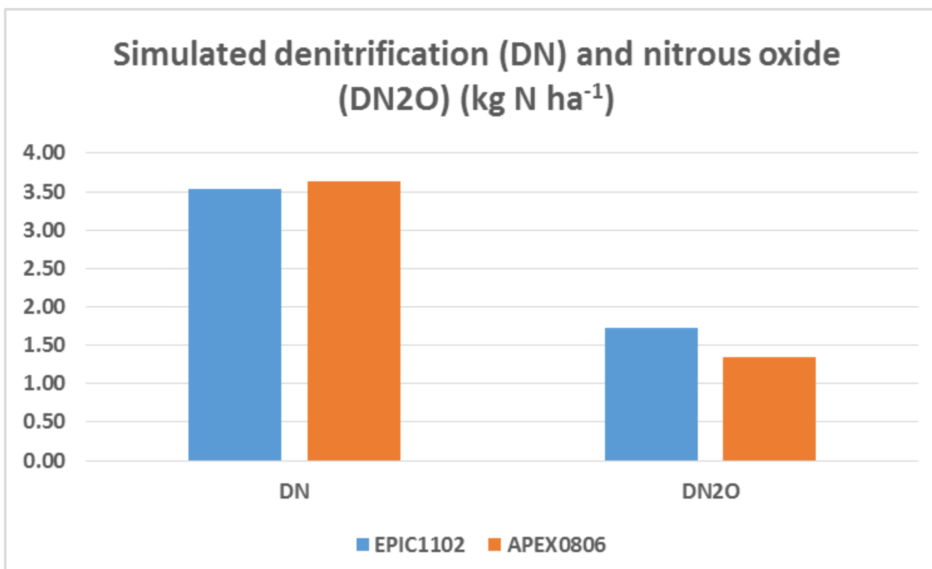




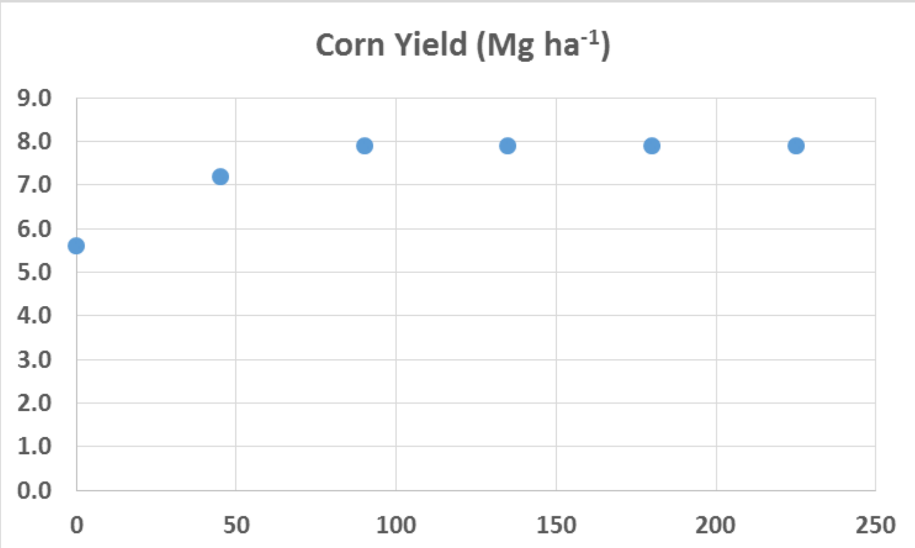


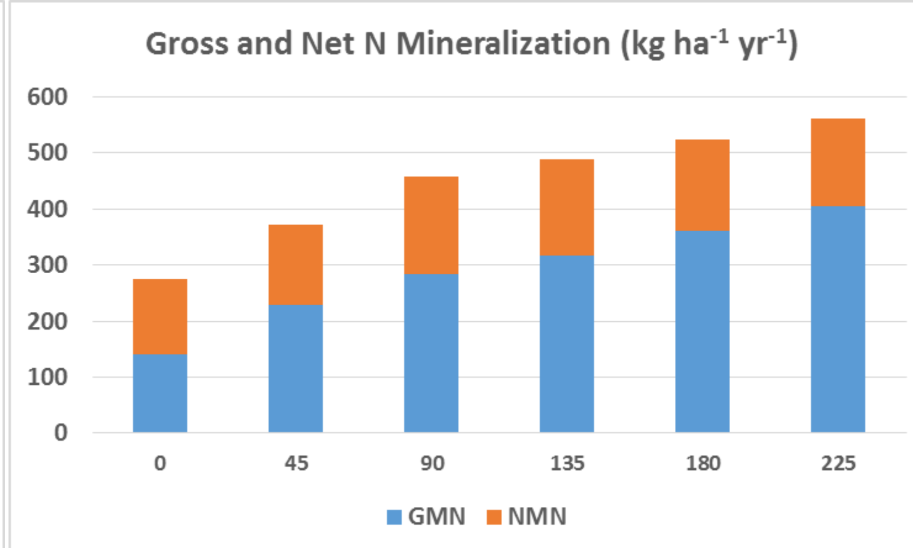
Simulated vs. observed annual and seasonal N_2O flux ($g\ N_2O\text{-}N\ ha^{-1}\ d^{-1}$) in a corn – soybean – wheat rotation at KBS

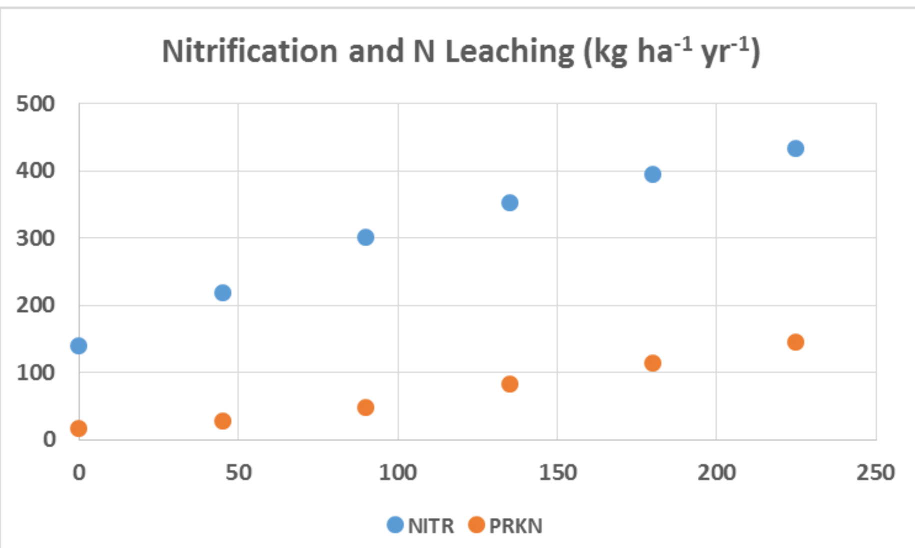


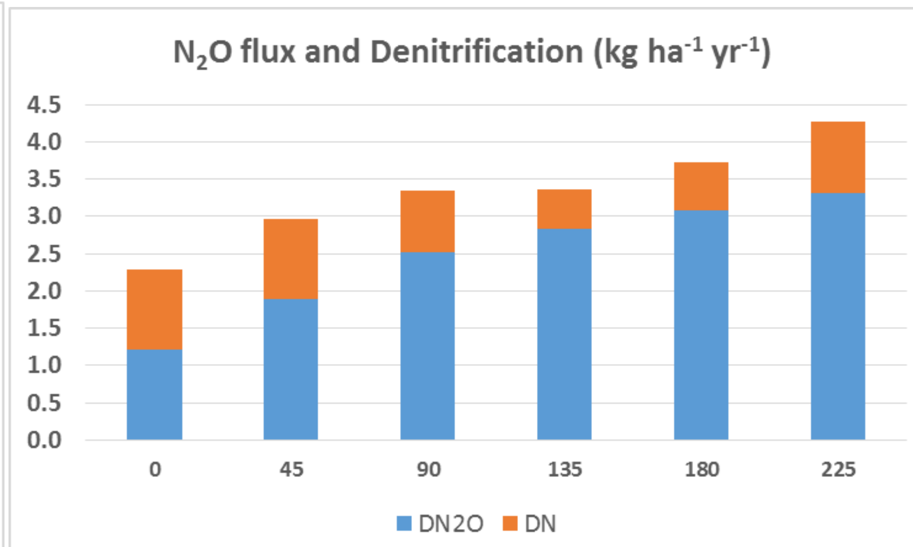


How does APEX simulate crop yield, N mineralization, and N losses as affected by N rate?





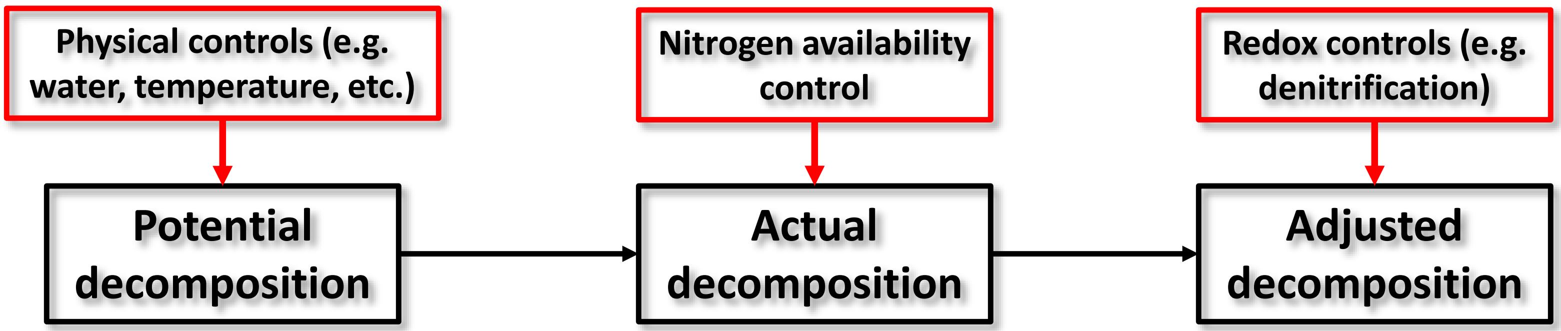




New water, C, and N features in EPIC and APEX

- Algorithms to describe C/N relationships of microbial biomass based on the Phoenix model (McGill et al. 1981)
- Soil organic matter decomposition adjusted for anaerobic conditions when redox reactions occur (e.g. denitrification, methanogenesis)
- Allow microbial activity down to temperatures of -8 °C by accounting for liquid water and ice
- Nitrification equations enhanced to account for pH effects on NO_2^- accumulation
- Stoichiometric treatment of O_2 uptake and heterotrophic CO_2 release by soils
- New percolation subroutines to slow down emptying of pores in upper layers (slug approach)

EPIC-APEX approach to describe Soil Organic Matter decomposition



Summary

- Based on EPIC algorithms, a new version of the APEX model was developed with capabilities to model biogeochemical processes in terrestrial ecosystems
- Favorable comparisons can be obtained with EPIC and APEX for selected outputs (e.g. yield, water, carbon, nitrogen) but further work is needed to ensure full comparability
- Testing and improvement of APEX will continue with particular attention to:
  - Biogeochemical processes in wetlands and rice paddies
  - Transport and deposition of eroded carbon and nitrogen across fields