Integrated Watershed Modeling and Accounting of Terrestrial and Aquatic Carbon Budgets

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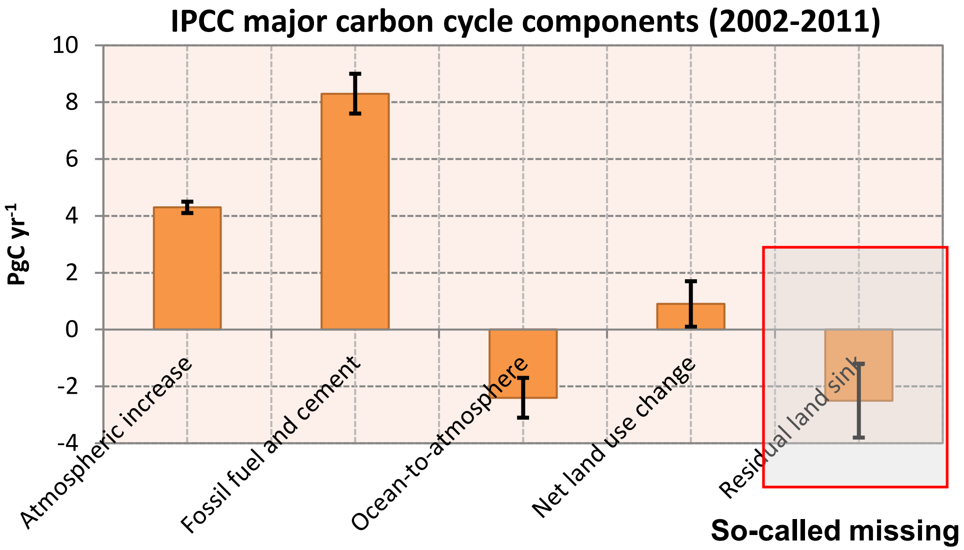
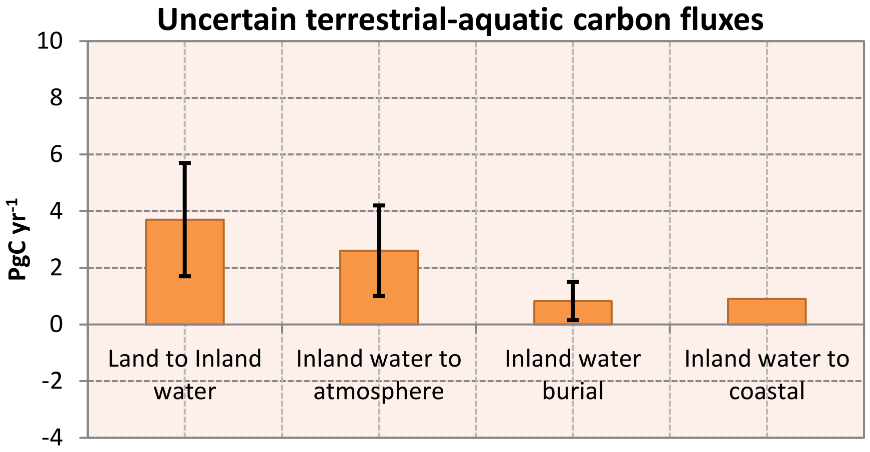
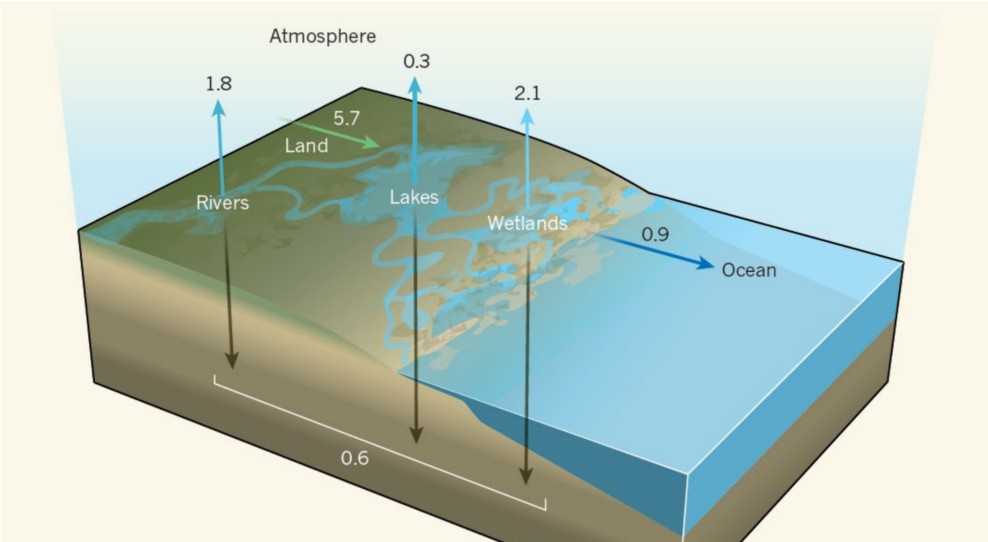
Incomplete accounting of terrestrial-aquatic carbon fluxes







Bernhard Wehrli, 2013

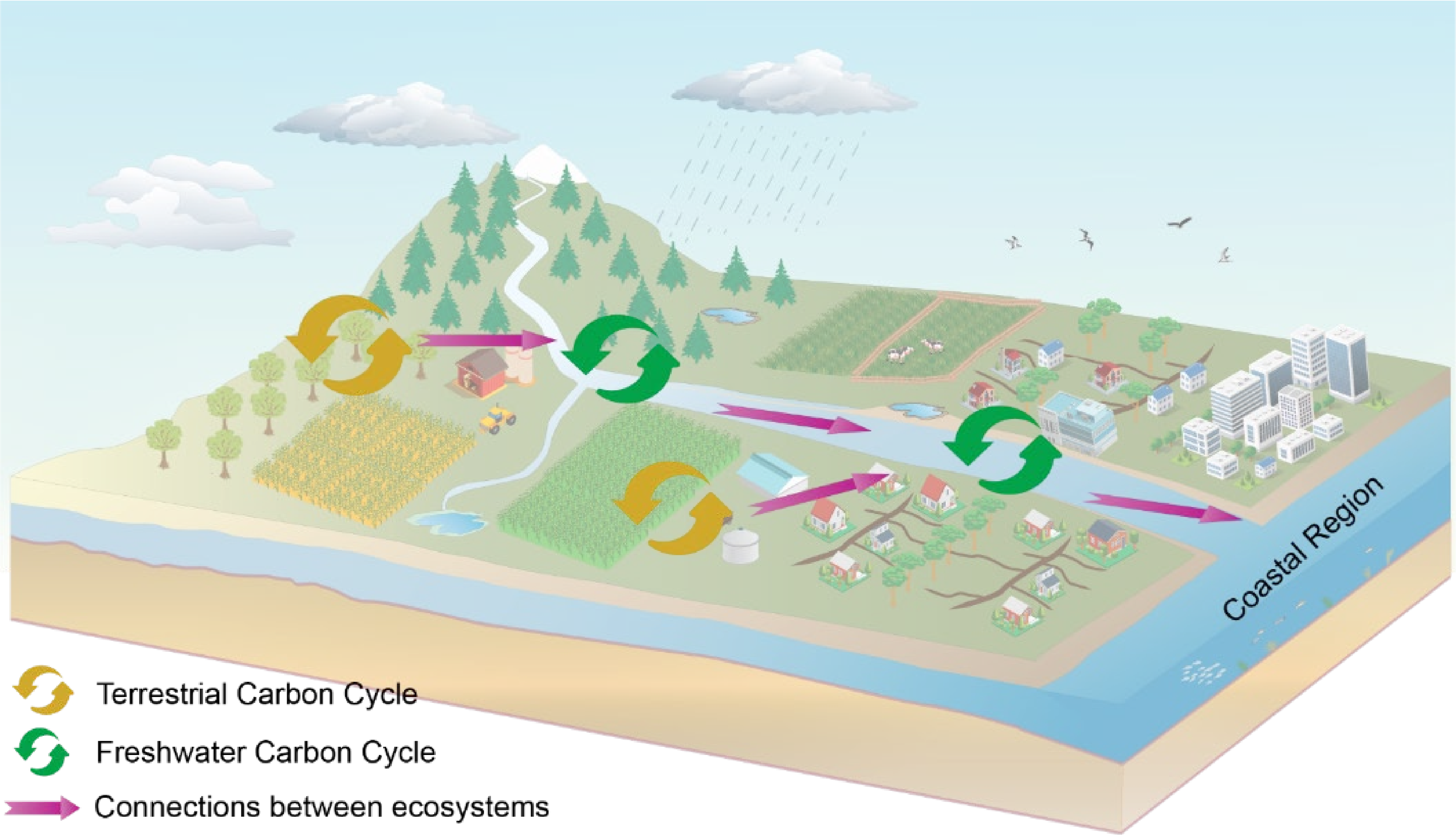
Recent results indicate that aquatic fluxes subject to significant uncertainty:

- Land to Inland water: 1.7 - 5.7 PgC yr^{-1}
- Inland water to atmosphere: 1.0 – 3.88 PgC yr^{-1}
- Inland water burial: 0.15 - 1.6 PgC yr^{-1}

(Ciais et al., 2013, Tranvik et al., 2009, Wehrli, 2013, Aufdenkampe et al., 2011, Mendonça et al., 2017, Stallard, 1998, Bastviken et al., 2011, Cole et al., 2007, Raymond et al., 2013, Sawakuchi et al., 2017, Drake et al. 2018)

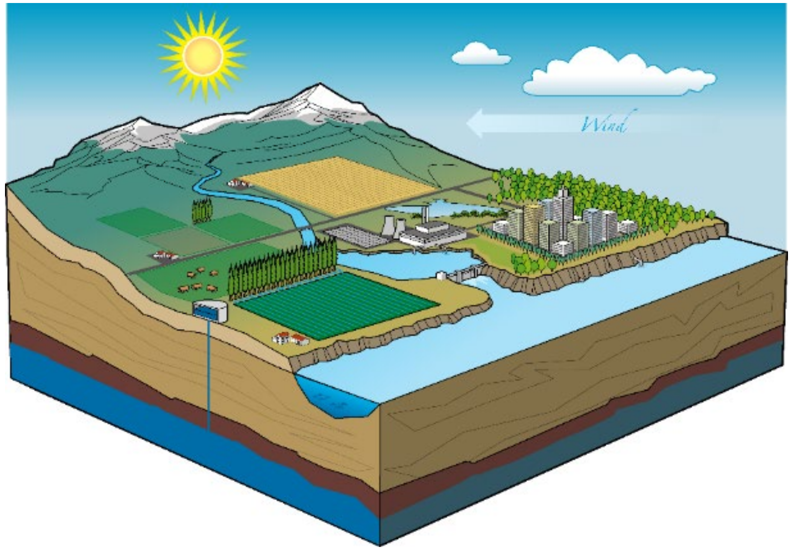
Guiding principles

https://sites.google.com/view/tasc-carbon

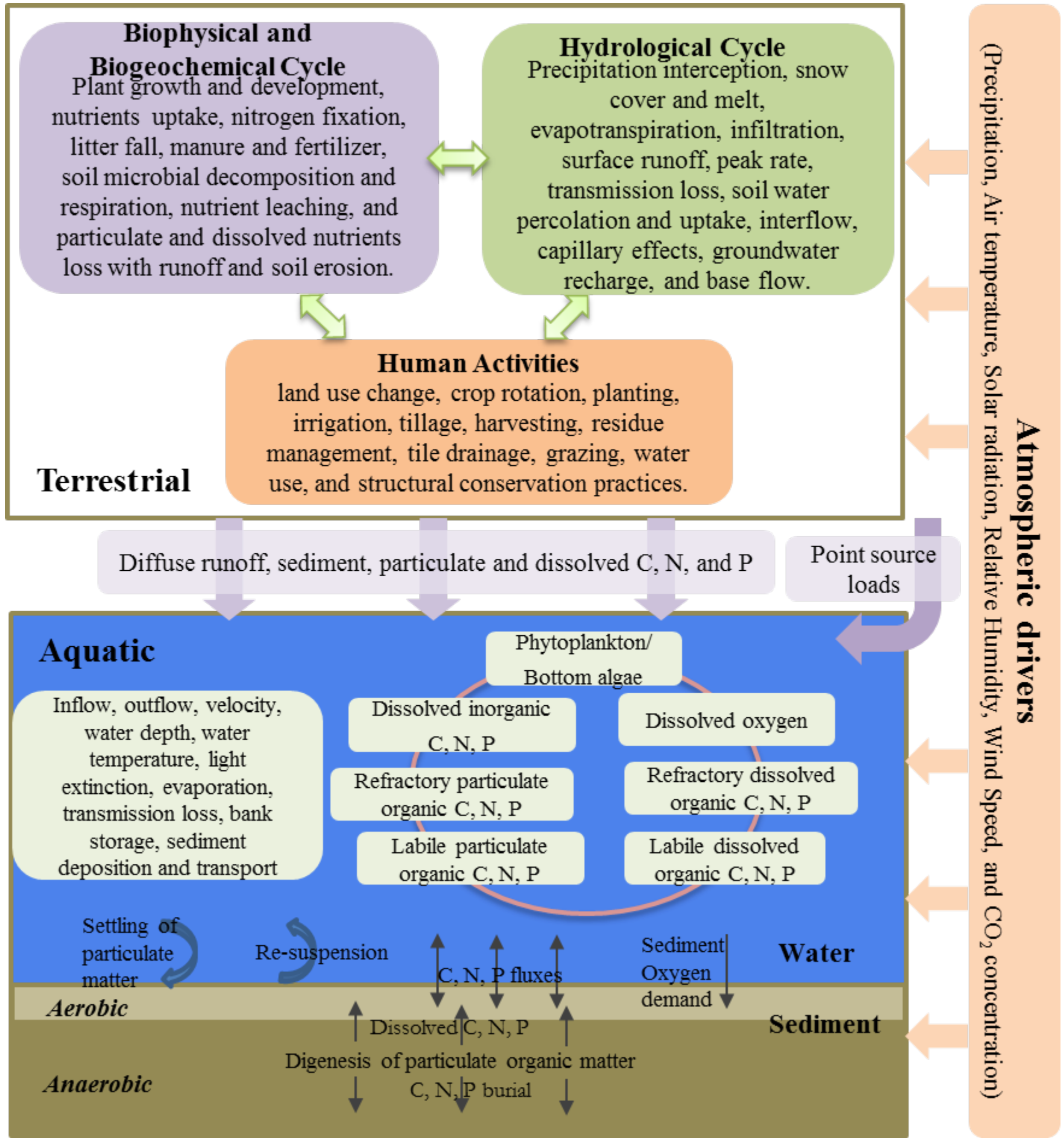


Put together pieces of the watershed scale carbon cycling puzzle

Watershed modeling: The Terrestrial and Aquatic Sciences Convergence (TASC) model



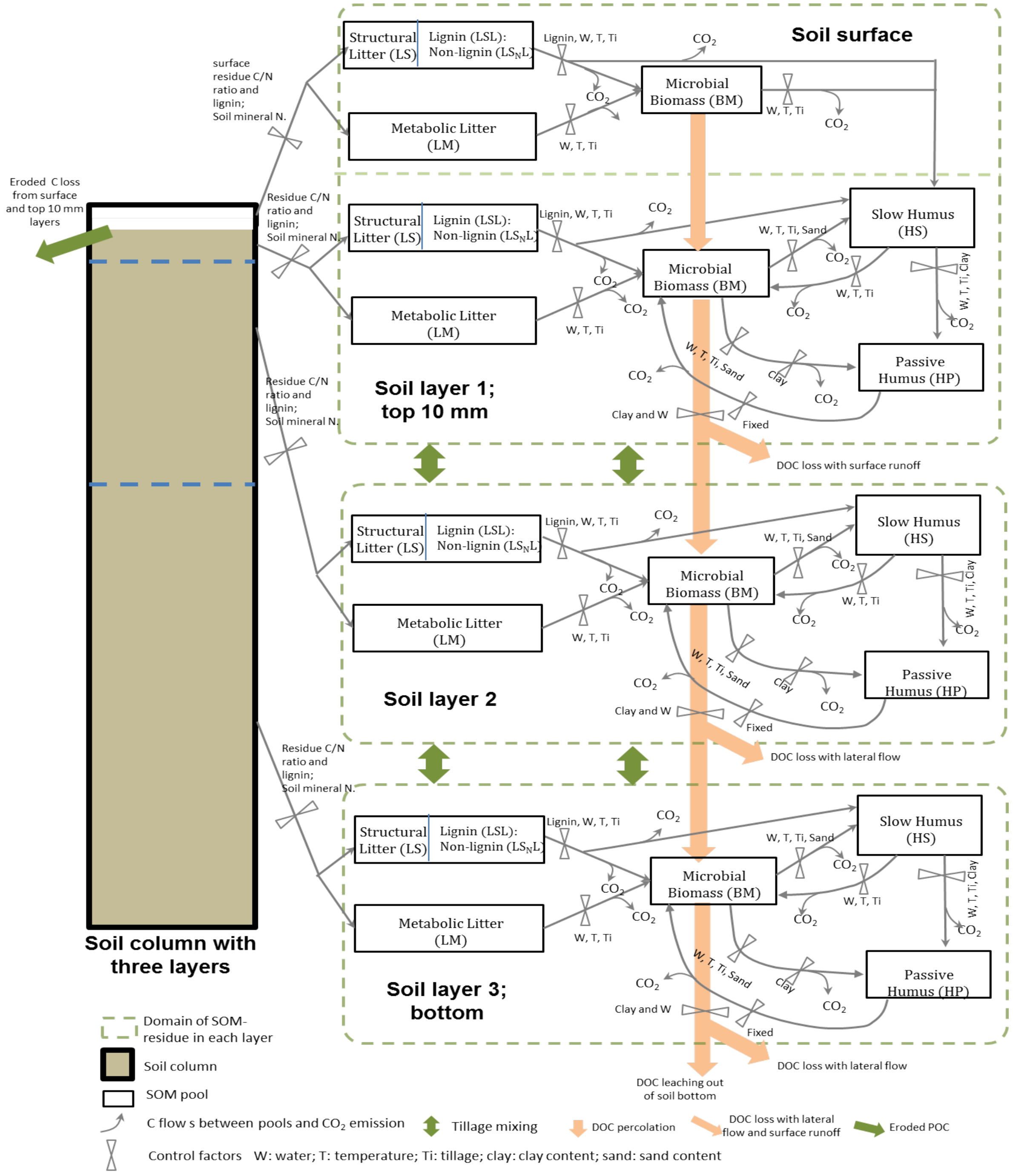
- Based on the widely used Soil and Water Assessment Tool (SWAT) that has been reported in over 7,000 peer reviewed journal articles
- Key improvements:
  - Terrestrial: CENTURY, EPIC, DSSAT, DNDC, and recent literature (Zhang et al. 2013, 2018; Liang et al. 2022).
  - Aquatic: QUAL2K and CE-QUAL-W2 (Du et al. 2019; Qi et al. 2019)



https://sites.google.com/view/tasc-carbon

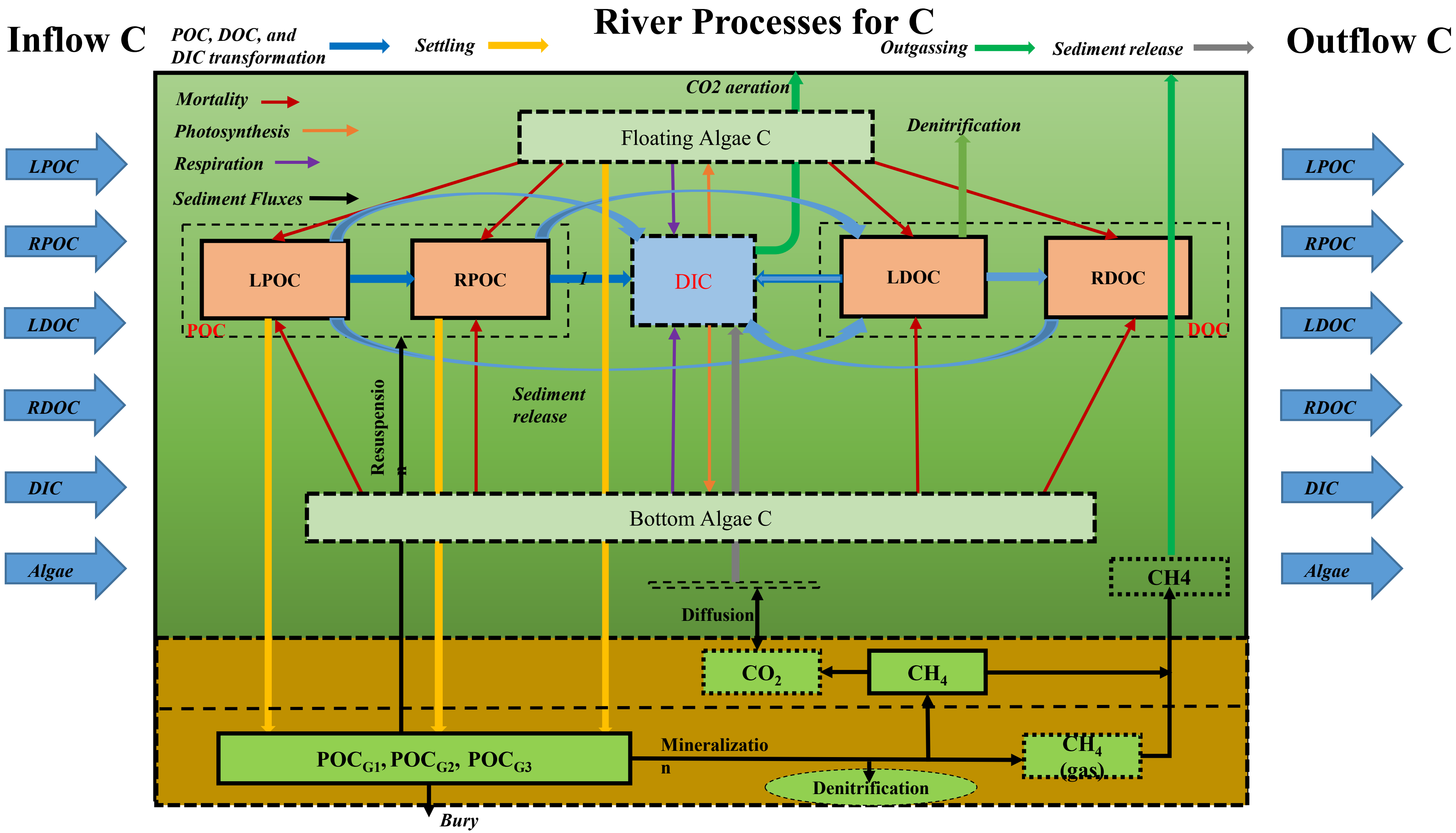
Terrestrial carbon module

- Schematic representation of new SOM-residue dynamics in TASC.
- Algorithms are derived from CENTURY, EPIC, DSSAT, DNDC, and ORCHIDEE.



Zhang, X., Izaurralde, R.C., Arnold, J.G., Williams, J.R. and Srinivasan, R., 2013. Modifying the soil and water assessment tool to simulate cropland carbon flux: model development and initial evaluation. *Science of the Total Environment*, *463*, pp.810-822.

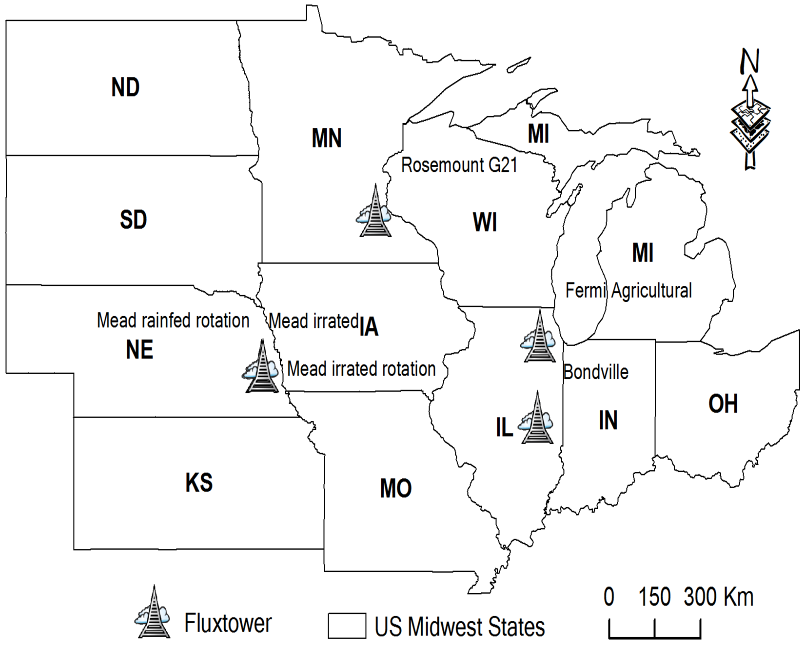
Continued development and evaluation of aquatic carbon processes



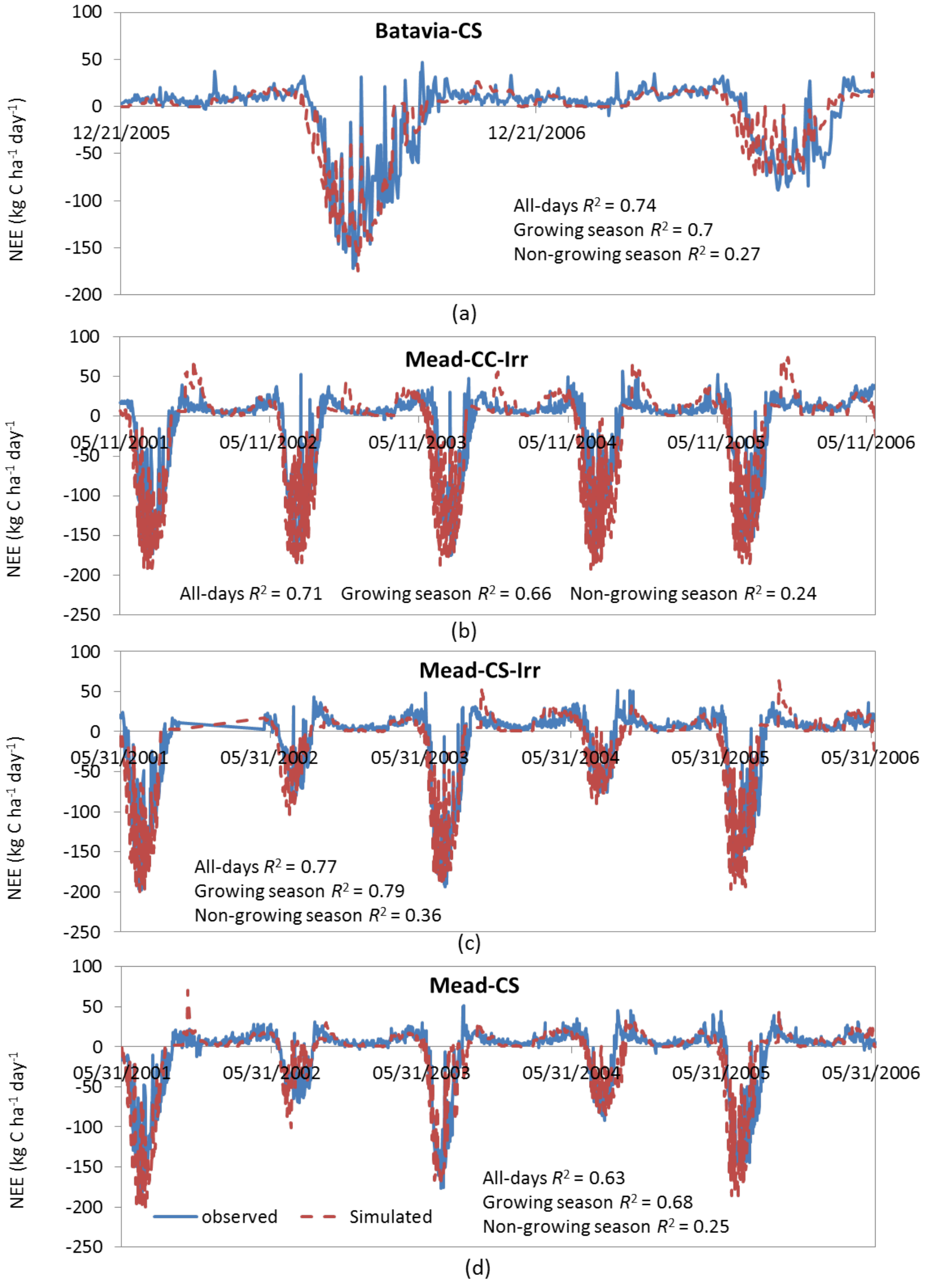
Du, X., Zhang, X., Mukundan, R., Hoang, L. and Owens, E.M., 2019. Integrating terrestrial and aquatic processes toward watershed scale modeling of dissolved organic carbon fluxes. *Environmental Pollution*, *249*, pp.125-135.

Qi, J., Zhang, X., Lee, S., Wu, Y., Moglen, G.E. and McCarty, G.W., 2020. Modeling sediment diagenesis processes on riverbed to better quantify aquatic carbon fluxes and stocks in a small watershed of the Mid-Atlantic region. *Carbon Balance and Management*, *15*(1), pp.1-14.

Evaluating TASC for simulating cropland carbon fluxes at AmeriFlux towers



Comparison of SWAT-C simulated and flux tower observed Net Ecosystem Exchange (NEE)



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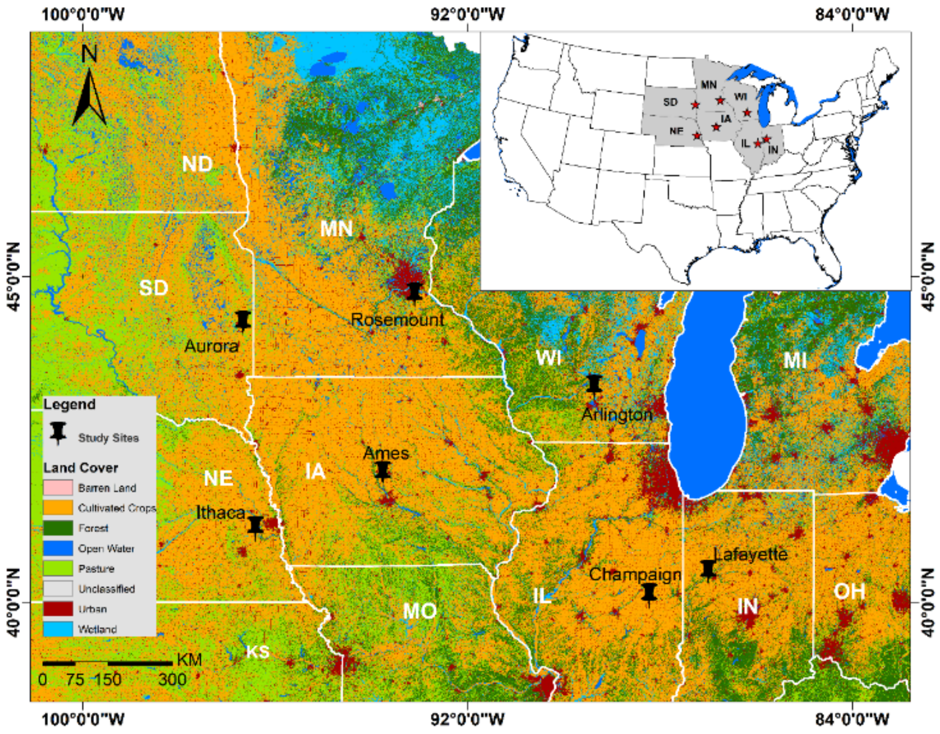
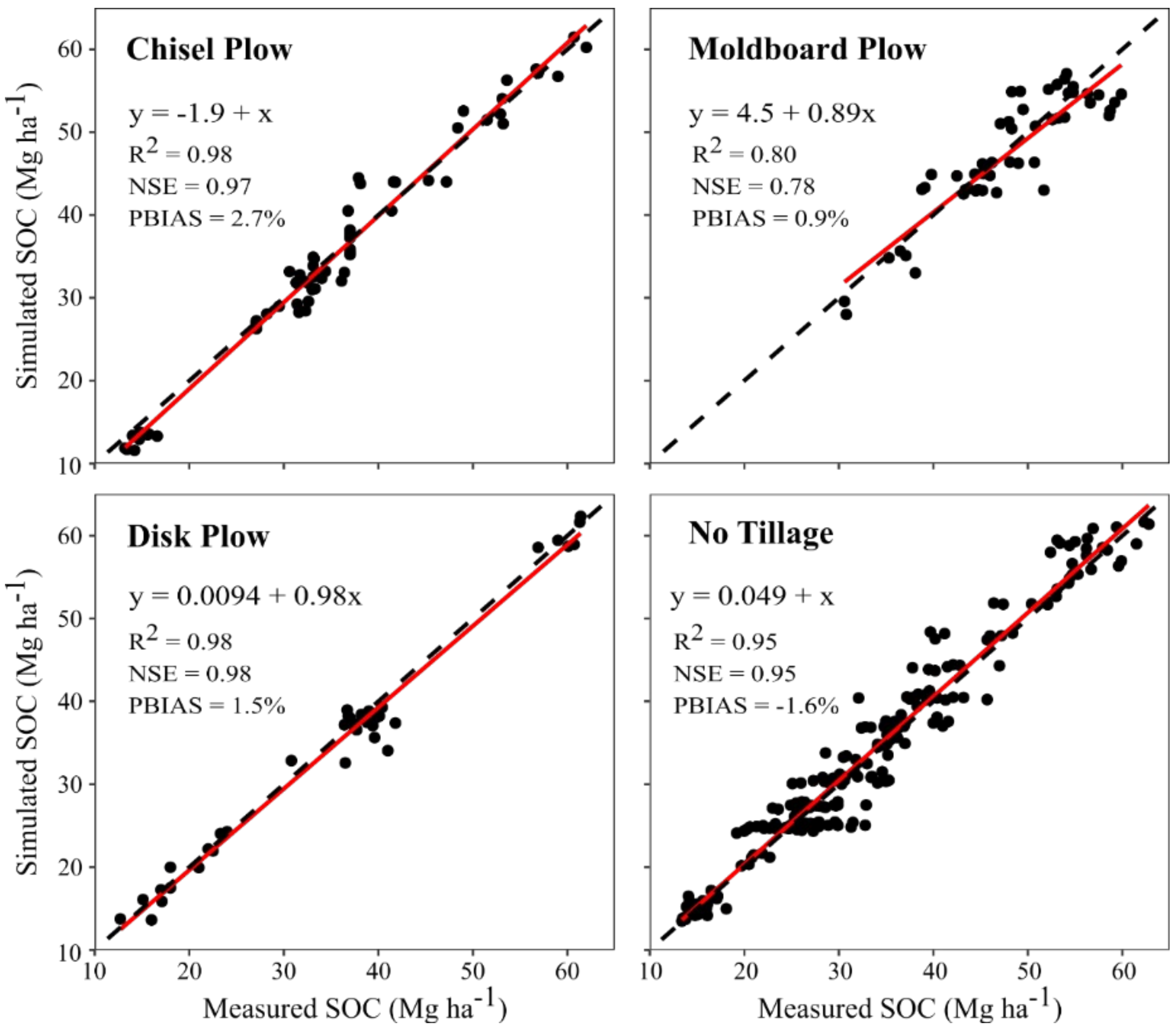
Evaluation of TASC for soil organic carbon simulation

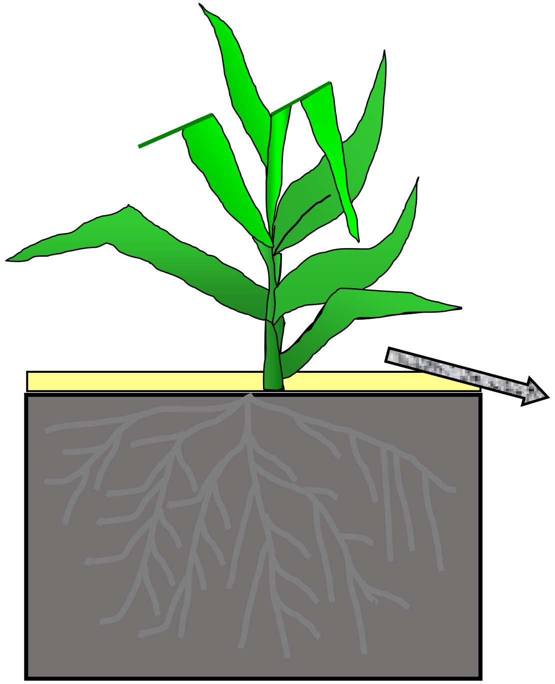


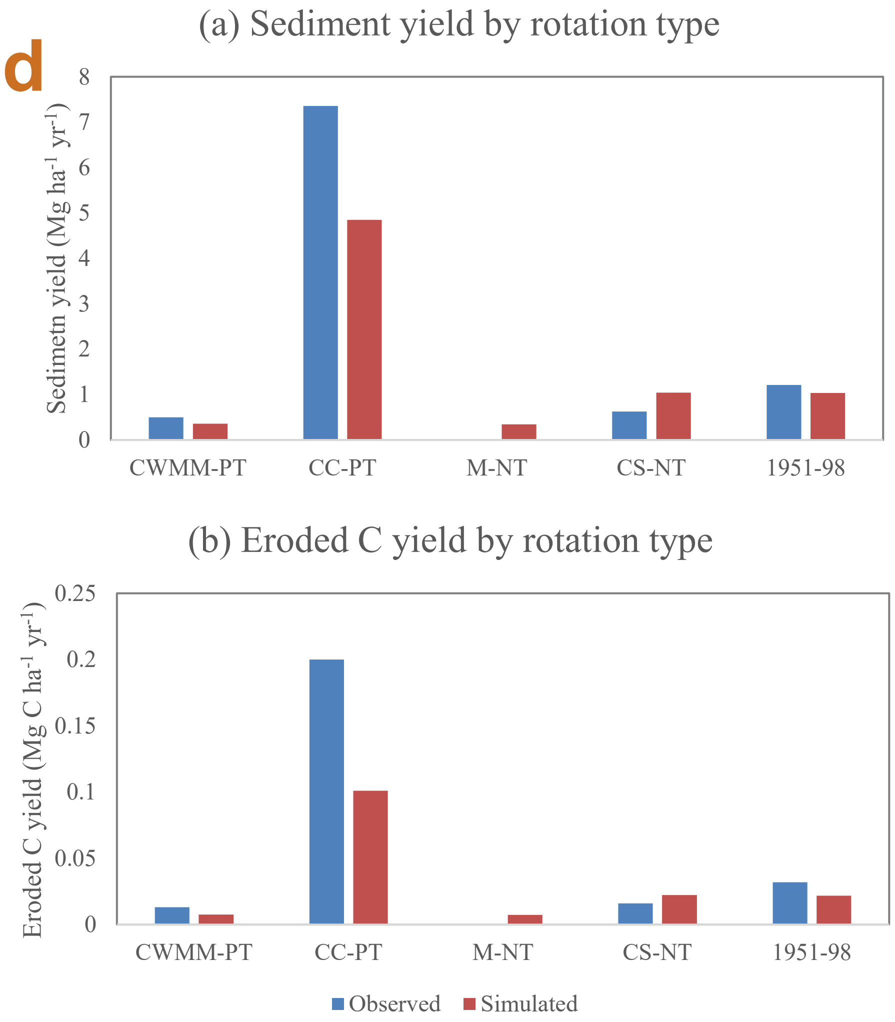
Liang, K., Qi, J., Zhang, X. and Deng, J., 2022. Replicating measured site-scale soil organic carbon dynamics in the US Corn Belt using the SWAT-C model. *Environmental Modelling & Software*, *158*, p.105553.



Evaluating TASC for simulating eroded soil organic carbon

$$\text{Eroded}_{SOC} = Soil\_Erosion \times SOC_{content} \times \text{Enrichment\_ratio}$$



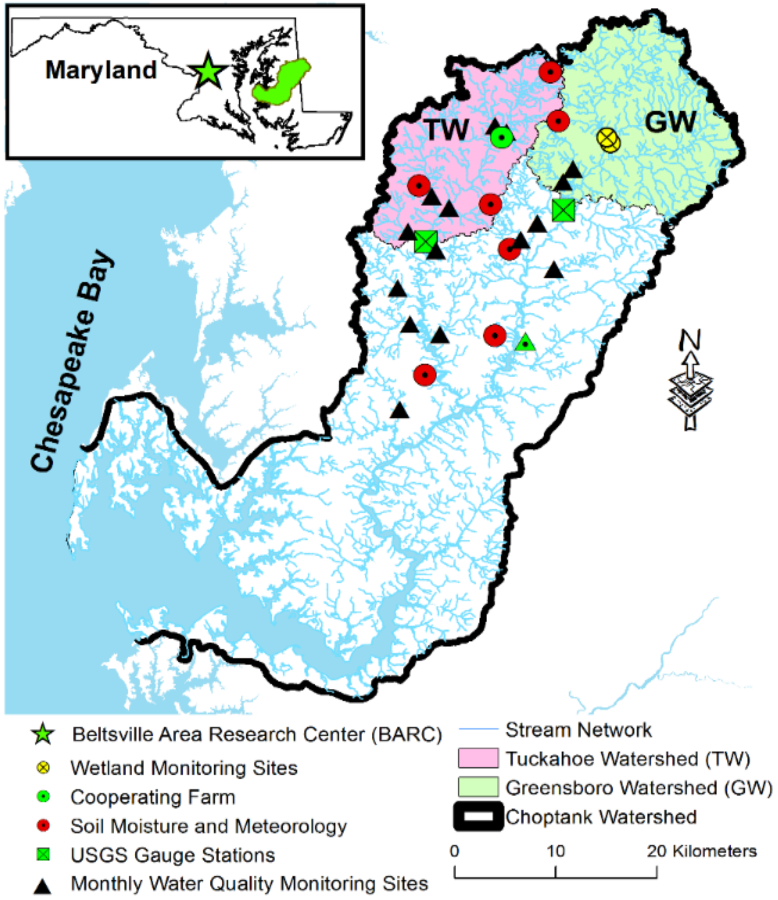


Sediment and eroded C yields for different crop rotations. 1951-1970: CWMM-PT; 1971-75: CC-PT; 1976-1983: M-NT; 1984-1998: CS-NT.

The experimental site is a small watershed (W118) located within the USDA's NAEW research station (40° 22' N, 81° 48' W) near Coshocton, Ohio.

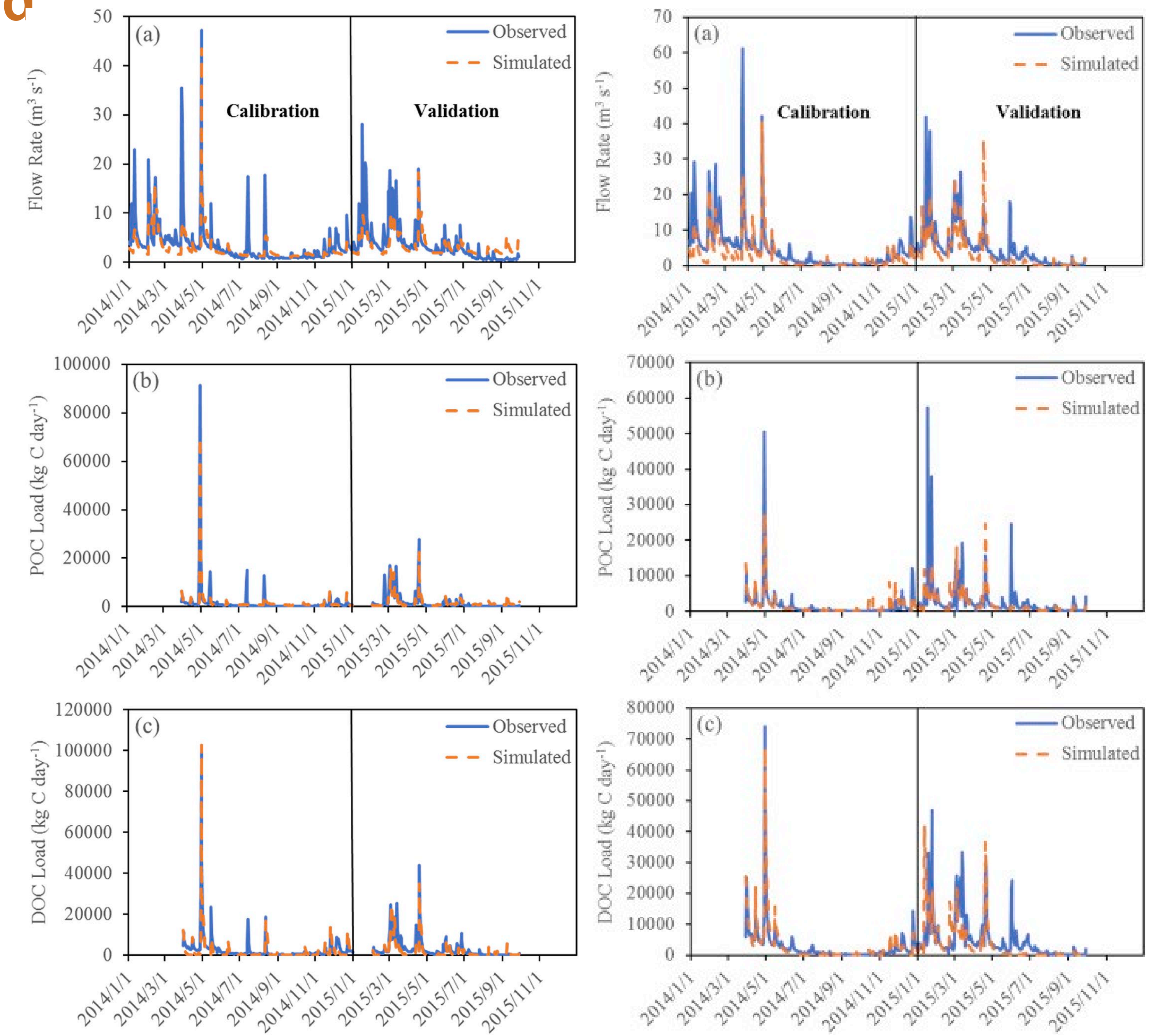
Zhang, X., 2018. Simulating eroded soil organic carbon with the SWAT-C model. *Environmental Modelling & Software*, *102*, pp.39-48.

Model Evaluation for POC and DOC fluxes



Tuckahoe Watershed

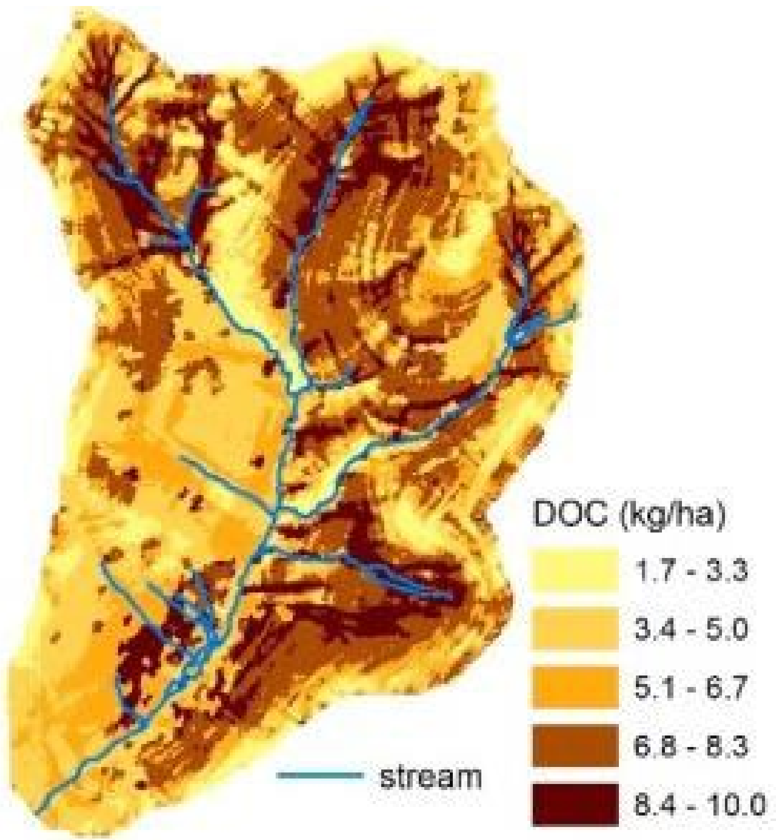
Greensboro Watershed

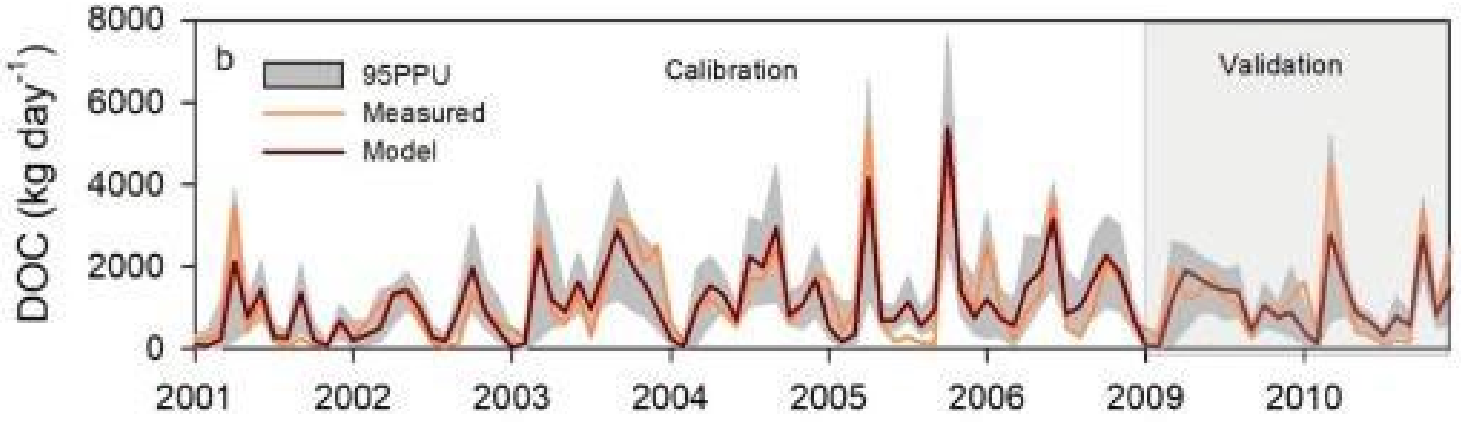


Qi, J., Du, X., Zhang, X., Lee, S., Wu, Y., Deng, J., Moglen, G.E., Sadeghi, A.M. and McCarty, G.W., 2020. Modeling riverine dissolved and particulate organic carbon fluxes from two small watersheds in the northeastern United States. *Environmental Modelling & Software*, *124*, p.104601.

Dissolved Organic Carbon Production from Variable Source Areas

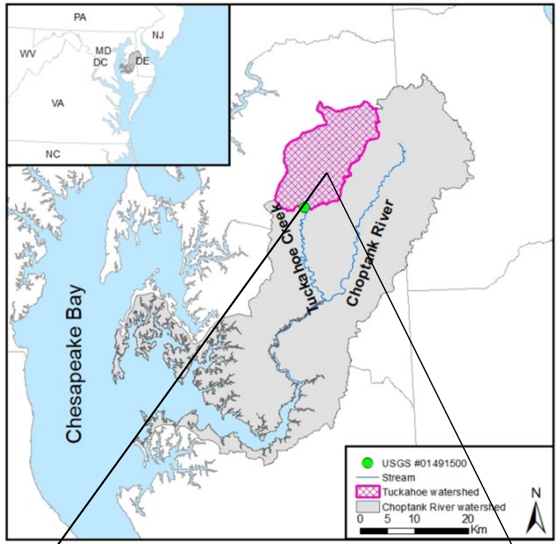
- New York City's Water Supply Watersheds (e.g., Neversink Reservoir watershed)



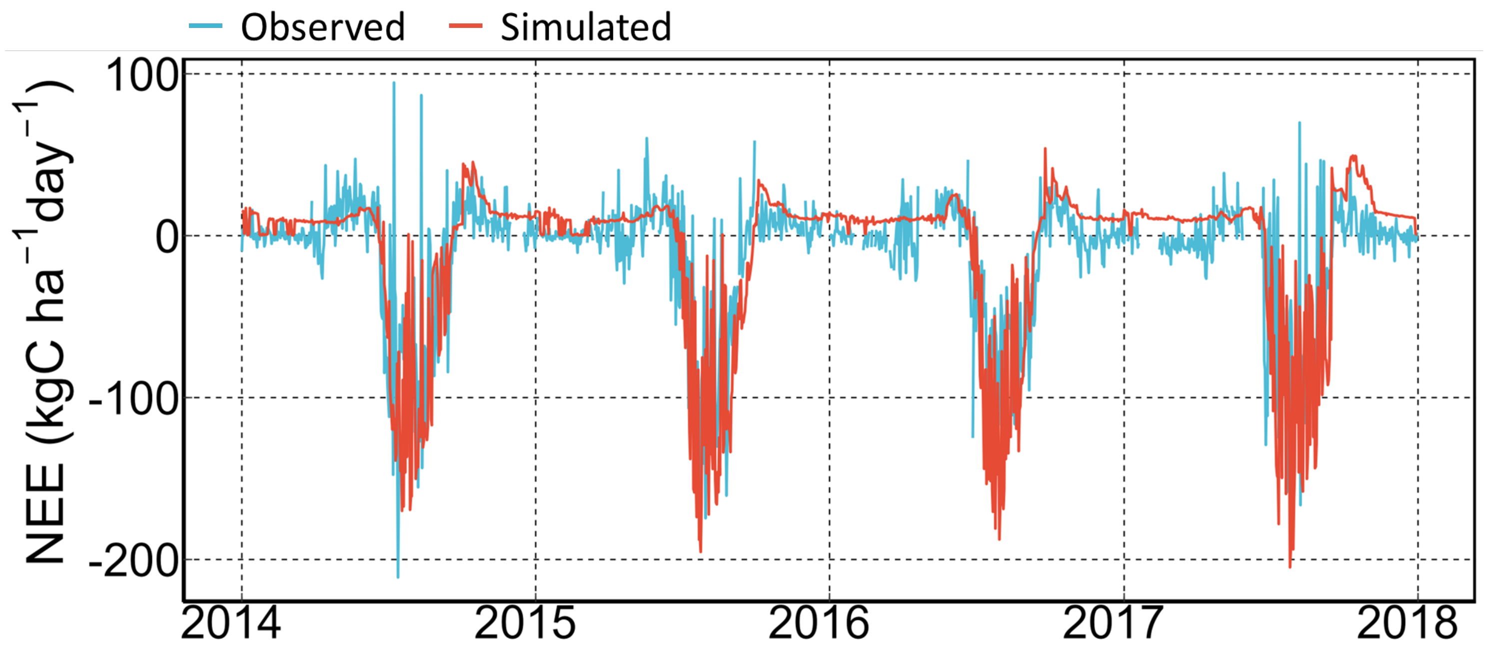


Mukundan, R., Gelda, R., Moknatian, M., Zhang, X. and Steenhuis, T., 2023. Watershed Scale Modeling of Dissolved Organic Carbon Export from Variable Source Areas. *Journal of Hydrology*, p.130052.

Case Study 1. Model simulation of Net Ecosystem Exchange at a corn field



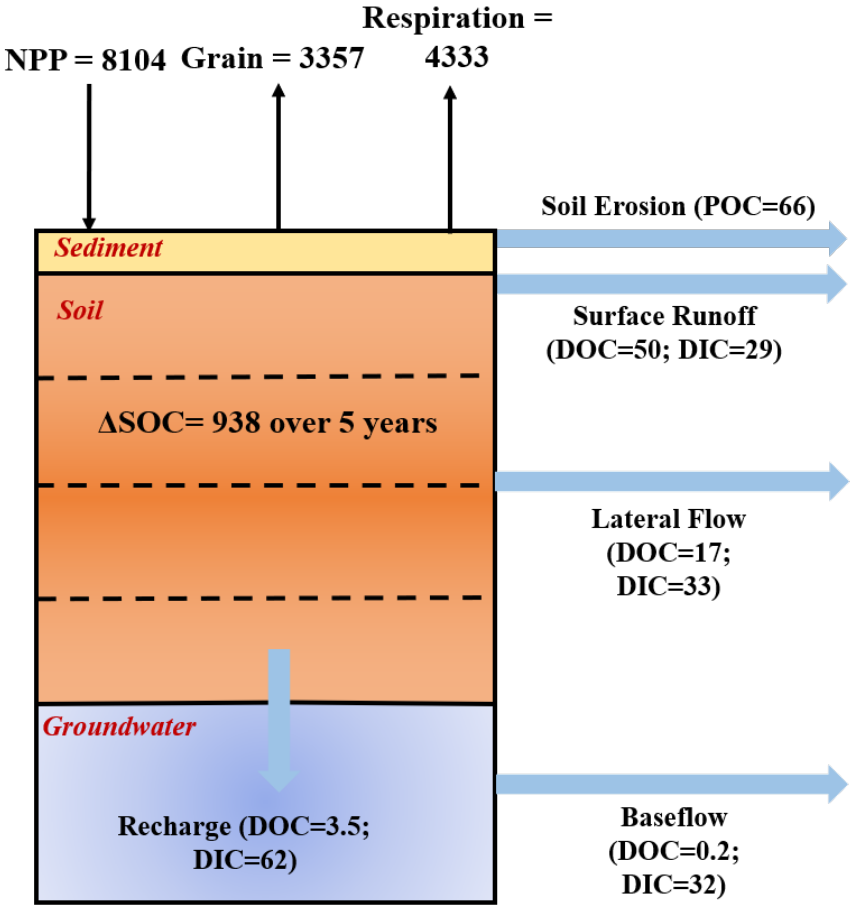
Lower Chesapeake Bay Long-Term Agriculture Research Site



Simulated and flux tower observed NEE from a corn field in the Tuckahoe Watershed.

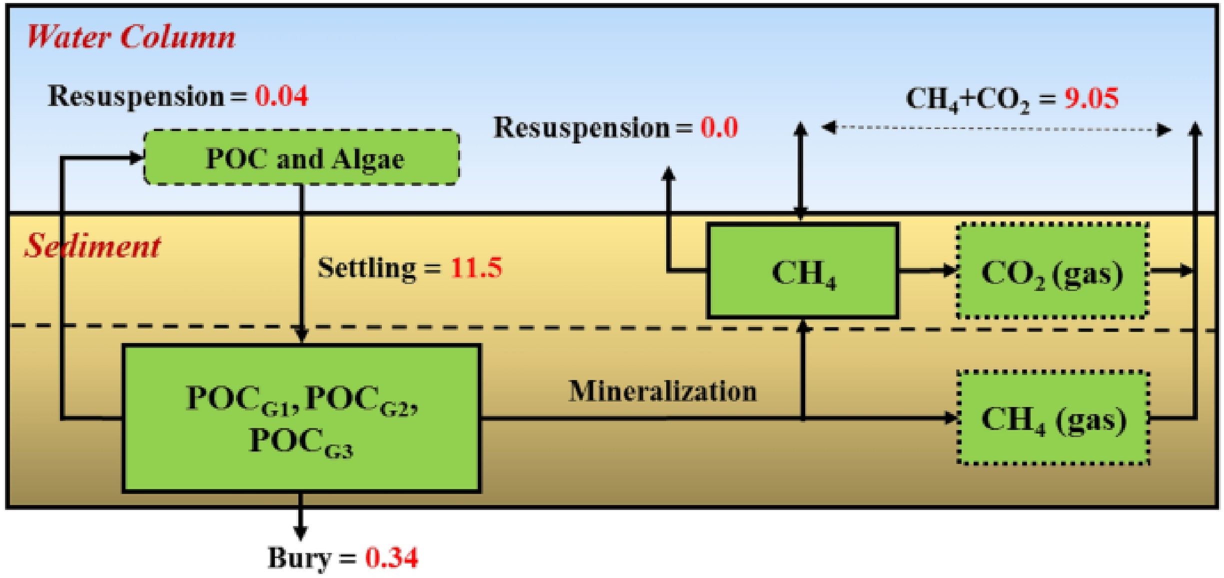
The TASC model simulated average daily NEE was -13.4 kgC ha^{-1}, slightly lower than the observed daily average of -12.4 kgC ha^{-1}. The correlation between the time series of observed and simulated daily NEE is 0.73.

Significance of lateral carbon fluxes and ongoing efforts to elucidate the fate of laterally transported carbon



SOC stocks: increase ca. 187 kg C $year^{-1}$ ha^{-1}

Lateral carbon fluxes: 227 kg C $year^{-1}$ ha^{-1}



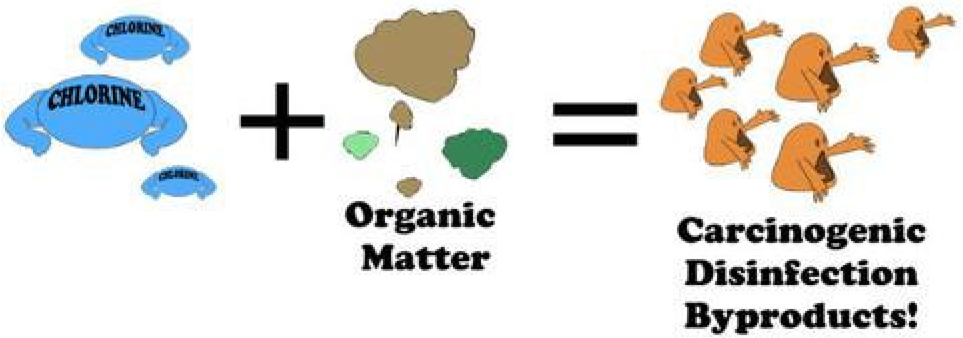
The fate of the laterally transported carbon in the downstream aquatic environments is very complex and uncertain. For example, eroded POC can be deposited to reiver bed, decomposed to CO2 and CH4, resuspended during flooding, and discharged outside of the watershed.

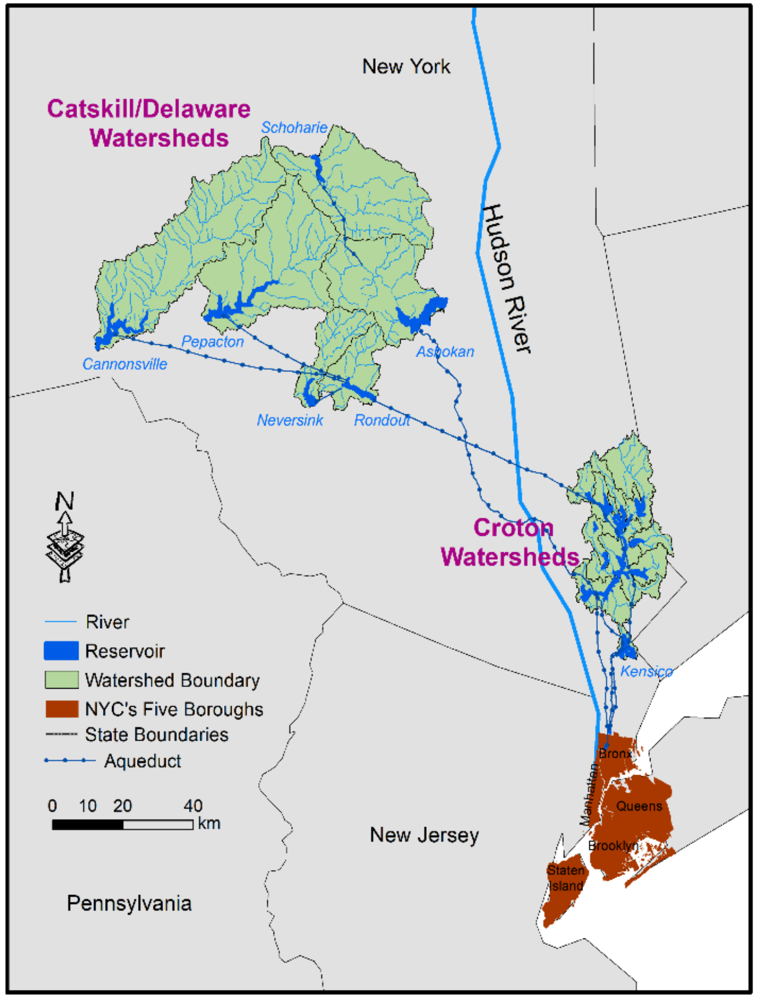
Luo, X., Risal, A., Qi, J., Lee, S., Zhang, X., Alfieri, J.G. and McCarty, G.W., 2024. Modeling lateral carbon fluxes for agroecosystems in the Mid-Atlantic region: Control factors and importance for carbon budget. *Science of The Total Environment*, *912*, p.169128.

Qi, J., Zhang, X., Lee, S., Wu, Y., Moglen, G.E. and McCarty, G.W., 2020. Modeling sediment diagenesis processes on riverbed to better quantify aquatic carbon fluxes and stocks in a small watershed of the Mid-Atlantic region. *Carbon Balance and Management*, *15*, pp.1-14.

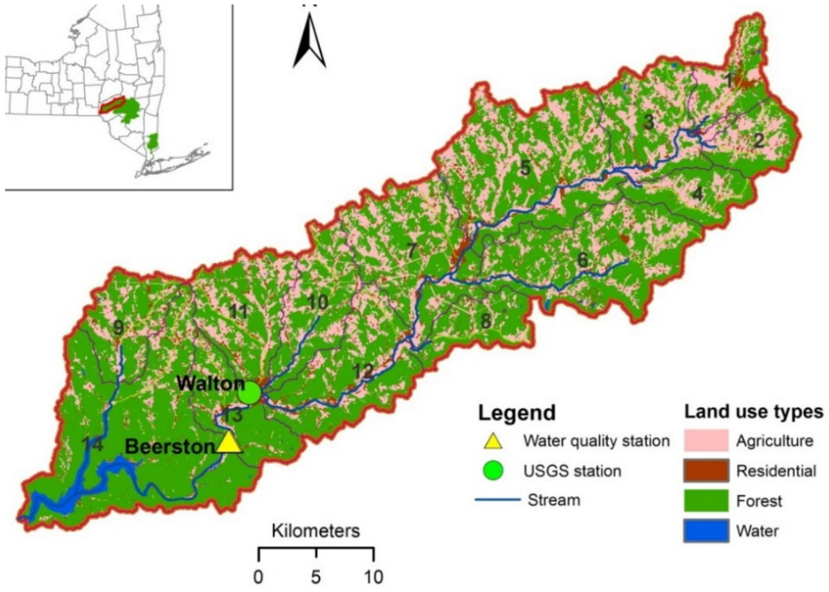
Case Study 2: The need of reducing dissolved organic carbon in NYC's water supply watersheds

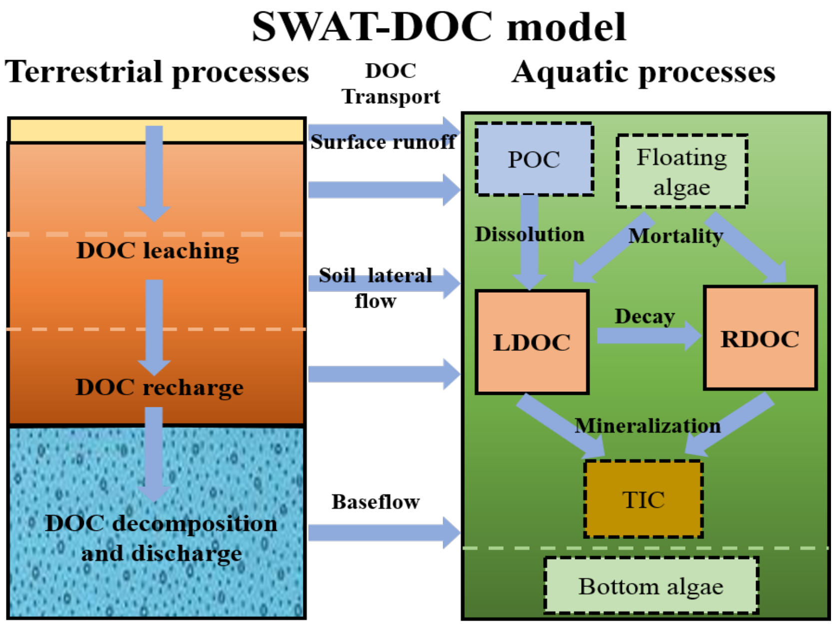
Cannonsville Reservoir

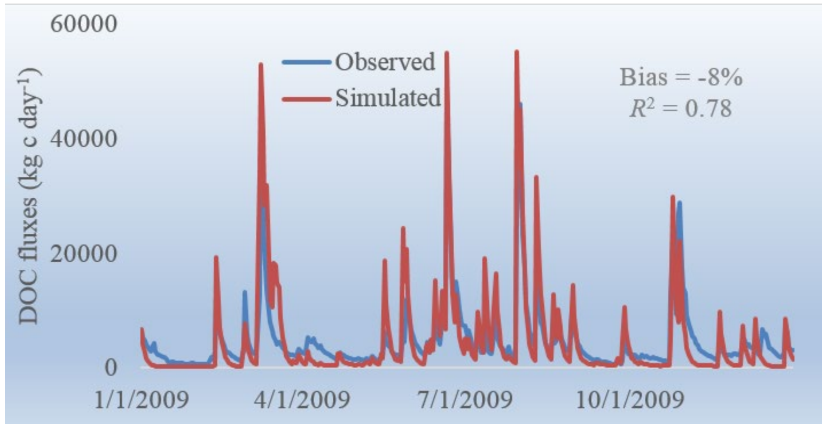




DOC modeling in NYC source watersheds: Cannonsville







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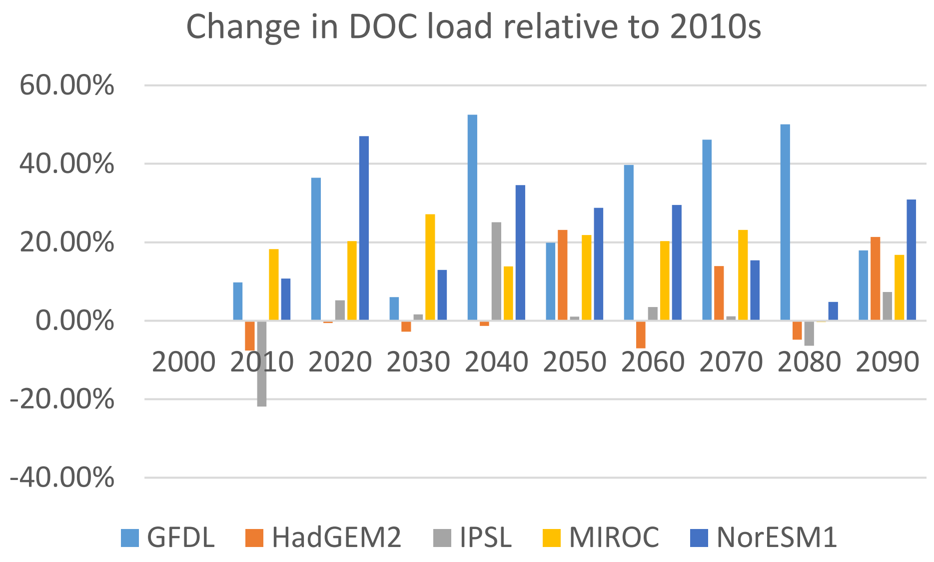
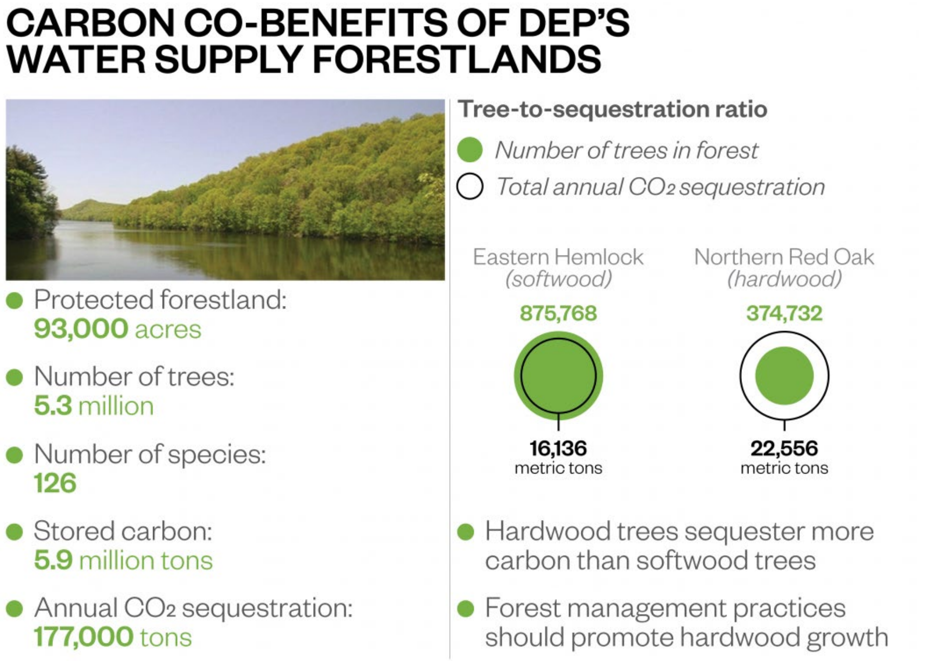
Balancing different carbon cycle impacts





www.hazenandsawyer.com/work/projects/nycdep-water-energy-nexus-study/

Filtration Plant:

Upwards of $10 billion for construction +
$200-400 million for operation and maintenance/year

Forest carbon sequestration benefits:

$17.7 million/year
With a carbon price at $100/Ton CO_2
(Jeff McMahon 2019, Forbes)