Simulating the Tug of War Between Transport and Nutrient Uptake in Low Flow Treatment Wetlands Demonstrates the Need to Model Biogeochemistry

Kalindhi Larios Mendieta and Dr. Stefan Gerber
Soil and Water Sciences Department, University of Florida
Introduction: Constructed Wetlands

(Mitsch and Gosselink, 2007)

1. Hydrology
   - Water level, flow, frequency, etc.

2. Physiochemical environment
   - Sediments, soil chemistry, water chemistry, etc.

3. Biota
   - Vegetation, animals, and microbes

(Mitsch and Gosselink, 2007)

Construction wetlands are:

1. Human made
2. Low-tech water treatment systems
3. Take advantage of natural wetland processes between biota, soil, and water for nutrient removal (Vymazal 2010)
Wetland treatment efficiency is dependent on water transport.
- Transport varies temporally and spatially

This creates slow and fast velocity flow pathways!
Wetland Hydrology: Transport

There has been a focus on modeling hydrology over biogeochemical cycling

• Due to spatial heterogeneity creating slow-fast flow paths
• BUT in low flow wetlands biogeochemical processes become important
Research Objective:
Explore the effects of flow rate on outflow Total Phosphorus (TP)

Hypothesis:
Differences in the numerical representation of hydrology will have larger effects on outflow TP concentration than differences in the biogeochemistry representation.
Study Site: Everglades STA-2 FW 1
Methodology: Hydrology Models

1) Plug Flow

- Laminar Flow: No Mixing
- Constant Average Flow Rate or Varying Flow Rate (Q)

2) Tank In Series

- Turbulent-Laminar Flow: Mixing
- PDF of Hydrologic Residence Time
- Parcels of water can lag (Bykhovsky 2016)
  - Memory
Methodology: Biogeochemistry Models

- **First Order C* Model**
  - 2 parameters
  - Describes uptake from all wetland components into 1 parameter called the uptake coefficient
  - Considers a background TP concentration

- **Transient Storage Model**
  - 3 parameters
  - Describes main wetland channel uptake and uptake from zones of slow flow (Transient Storage)

- **Spiraling Model**
  - 43 parameters
  - Describes the physical, chemical, biological processes in a wetland
    - Resuspension, Settling, Soil Burial, Sorption, Uptake, Decomposition
Methodology: Experimental Set-Up

<table>
<thead>
<tr>
<th>Hydrology Model</th>
<th>Biogeochemistry Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug Flow: Varying Q</td>
<td>Spiral, Transient Storage, First Order Uptake</td>
</tr>
<tr>
<td>N-Tank In Series (relaxation=13d)</td>
<td>Spiral, Transient Storage, First Order Uptake</td>
</tr>
</tbody>
</table>

Inputs:
- Inflow TP concentrations
- Hydrologic data from STA-2 FW 1
  - 06/2005-12/2016

Outputs:
- Outflow TP concentrations

Hydrology + Biogeochemistry Model
Differences in Uptake With Plug Flow: Spiraling Model, Transient Storage, and First Order-C* Uptake

- First Order Uptake-C* + Plug Flow (Varying Velocity)
- Spiral + Plug Flow (Varying Velocity)
- Transient Storage + Plug Flow (Varying Velocity)
- Data
Differences in Uptake With Plug Flow: Spiraling Model, Transient Storage, and First Order-C* Uptake

TP Outlet Concentration (µg L⁻¹)

- First Order Uptake-C* + Plug Flow (Varying Velocity)
- Spiral + Plug Flow (Varying Velocity)
- Transient Storage + Plug Flow (Varying Velocity)
- Data

Time

2005
2010
2015
Differences in Uptake With Plug Flow: Spiraling Model, Transient Storage, and First Order-C* Uptake

- First Order Uptake-C* + Plug Flow (Varying Velocity)
- Spiral + Plug Flow (Varying Velocity)
- Transient Storage + Plug Flow (Varying Velocity)
- Data
Differences in Uptake With NTIS: Spiraling Model, Transient Storage, and First Order-C* Uptake
Model Comparison: Differences in Uptake & Hydrology

- First Order Uptake-C\(^\circ\) + Plug Flow
- First Order Uptake-C\(^\circ\) + NTIS (relaxation=13)
- Spiral + Plug Flow
- Spiral + NTIS (relaxation=13)
- Transient Storage + Plug Flow
- Transient Storage + NTIS (relaxation=13)
- Data

TP Outlet Concentration (μg L\(^{-1}\))

Time

2005 2010 2015
Summary

1. All model combinations are in the ballpark for simulating TP concentrations, so it really depends on the research objective.

2. The different numerical representations of flow lead to similar results.

3. Modeling biogeochemistry in low flow wetlands to understand treatment efficiency is just as important, if not more critical than modeling hydrology.