How to improve the representation of nitrate processes and their dynamics in eco-hydrological models?

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Motivation

- Nitrate entry in water bodies is one of the most pressing problems in agricultural watersheds.
- The process representation is highly complex and needs a sound parametrisation to develop realistic BMP‘s.
• Improved understanding of nitrate process representation by
  – Temporal sensitivity analysis of nitrate parameters
  – Simultaneous calibration of runoff and nitrate processes
  – Adding information to the calibration process by using FDG and NDC
Test catchment: Treene river in Northern Germany

- 481 km²
- Treia
- Lowland catchment
- Dominated by agricultural land use

Nitrate cycle in the SWAT-Model

<table>
<thead>
<tr>
<th>PARAMETER NAME</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of nitrogen in rainfall</td>
<td>RCN</td>
</tr>
<tr>
<td>Nitrate percolation coefficient</td>
<td>NPERCO</td>
</tr>
<tr>
<td>Denitrification exponential rate coefficient</td>
<td>CDN</td>
</tr>
<tr>
<td>Denitrification threshold water content</td>
<td>SDNCO</td>
</tr>
<tr>
<td>Rate factor for humus mineralization of active organic nitrogen</td>
<td>CMN</td>
</tr>
<tr>
<td>Nitrogen uptake distribution parameter</td>
<td>N_UPDIS</td>
</tr>
<tr>
<td>Half-life of nitrate in shallow aquifer</td>
<td>HLIFE_NGWfsh</td>
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</tbody>
</table>

*Haas et al. (2015).*
TEMPORAL SENSITIVITY ANALYSIS
Temporal dynamics of nitrate parameters in a daily resolution

- Temporal dynamics of parameter sensitivity (TEDPAS), (Reusser et al., 2011; Guse et al., 2014)
  - Identification of the dominant nitrate parameter/process for every day
  - Global sensitivity analysis with the FAST-Method (Fourier amplitude sensitivity testing)
  - Sensitivity varies between 0 and 1
Nitrate percolation coefficient \((\text{NPERCO})\) and uptake by plants \((\text{N.UPDIS})\)

- NPERCO controls the share of seepage of nitrate and the share in surface runoff. N_UPDIS controls the plant uptake from the soil.
The sensitivity of NPERCO is linked to the rainfall/runoff pattern and is sensitive over all seasons.

Aus Haas et al. (2015).
Daily sensitivity of N_UPDIS and Nitrate uptake of plants (NO3Crop)

N_UPDIS is linked to plant growth and thus shows a strong seasonality.
IMPROVED CALIBRATION PROCEDURE
Multivariable und multi-criteria calibration

- **Multivariable**: runoff + nitrate at the same time
- **Multi-criteria**: classical model efficiency measures + signature measures
- Flow duration curve (FDC) and nitrate duration curve
- (NDC)
  - **5FDC** Method (Pfannerstill et al., 2014):
    - Separate evaluation for every FDC segment
  - **5NDC** Method (Haas et al., 2016):
    - Efficiency measure calculated for every NDC segment

Exceedance probability \([\%]\)
Multi-variable und multi-criteria calibration

KGE = Kling-Gupta Efficiency (Gupta et al., 2009)
ED = Euklidic Distance

Haas et al. (2016, J.Hydrol.)
Best model (ED_Total) for runoff and nitrate load

Haas et al. (2016, J.Hydrol.)
Best model runs

Haas et al. (2016, J.Hydrol.)
TEMPORAL ANALYSIS OF BMP’S
Analysis of BMPs

Haas et al., 2017, JEMA
Reduction of nitrate by single BMPs

• Simulated BMPs
  – *Buffer strips* (BS)
    • 1,5 m; 3 m; 5 m; 6 m
  – *Reduction of fertilizer* (FR)
    • -15% and -30%
  – *Increase of pasture* (PLI)
    • +10% and +20%
  – *less silage mais* (RYC)
    • -50%
Seasonal reduction of nitrate loads caused by BMP’s
BMP combination matrix

BS = buffer strips  FR = fertilizer reduction  PLI = increase pasture  RYC = Alternative crop rotation
TEMPORAL ANALYSIS OF BMP’S
Main messages

• TEDPAS helps to identify WHEN a parameter is sensitive
• The application of different performance measures + signature measures (FDG/NDG) leads to a more balanced calibration
• NDC can be used to analyse the efficiency of BMPs
• Combination matrices of BMP‘s can support decision making
Thank you for your attention!

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Combining all values in one function

\[
\text{Euclidean Distance} = \sqrt{\sum \left( \frac{\text{Standardized measured value}}{\text{Standardized modelled value}} \right)^2}
\]

- The closer the Euclidean Distance to zero, the better the simulation