“An operational model for nutrient dynamics during flood events under anthropogenic impacts in a small mountainous catchment”

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The work is partly a PhD study financially supported by the German Ministry of Education and Research (BMBF) within the IPSWAT program
BACKGROUND

Wastewater discharge

Water quality pollution
BACKGROUND

- Water degradation (both quantity and quality) is increasing in the recent decades
- Difficult in controlling wastewater discharge in developing countries (point sources; illegal disposal)
- Non-point sources induced by e.g. extreme rainfall are ignored
- It is required an urgent need of powerful tools, integrated approaches for improving water quality management
Countries rely on mathematical models for water resources management

- EUROPE => Water Framework Directive “models are powerful tools for efficient water management and planning” (B. Arheimer, J. Olsson, 2005; Barlebo, et al., 2007)

- The US: Total Maximum Daily Load (TMDL) => “Models are the means of making predictions”; “Model results are the backbone of a TDML” (K. H. Reckhow et al, 2001; Lung, 2001)
To develop a robust model for watershed water quality management accounting for:

- Both point and non-point sources
- Limited data areas (ungauged catchment)
- Uncertainty analysis
STUDY AREAS

Total area (appr.) 21 km²
STUDY AREAS

Rainfall distribution
MODEL DEVELOPMENT

- Modelling objectives
- Scale issues (spatial and temporal)
- Model complexity (processes, model coupling)
- Limited data areas (ungauged catchment)
- Uncertainty analysis
MODEL DEVELOPMENT

1. Hydrology
   - Rainfall
     - Water losses due to interceptions, storages and infiltration
       - Runoff
         - Dissolved pollutants
         - River routing
           - Point sources
   - Soil detachment by rainfall
   - Soil detachment by runoff
   - Runoff transport capacity
   - Sediment supply
     - Particulate pollutants
     - Sediment Yield

2. Erosion/ sedimentation
   - Runoff
     - Soil detachment by runoff

3. Nutrient loadings
   - Dissolved pollutants
   - Particulate pollutants
   - River routing
   - Point sources

4. River routing

Diagram showing the flow of models and processes related to hydrology, erosion/sedimentation, nutrient loadings, and river routing.
MODEL FRAMEWORK

Hydrology: The Geomorphologic Instantaneous Unit Hydrograph

(Rodríguez-Iturbe et al 1979; Bras and Rodriguez-Iturbe, 1989; Nguyen et al, 2009)

- Coupling quantitative geomorphology and hydrologic modeling
- Lumped, empirical model
- Unit hydrograph is calculated by Geomorphologic parameters such as: bifurcation ratio, length ratio, area ratio based on DEM processing, and estimated flow velocity

\[ Q(t) = \int_{0}^{t} i(\tau)u(t - \tau) \, d\tau \]

\[ u(t) = \frac{\partial}{\partial t} \left( \sum_{Si} \text{Pr} \, \text{ob}(T_{Si} \leq t) \, \text{Pr} \, \text{ob}(S_i) \right) \]

\( \text{Pr} \, \text{ob}(S_i) \) is the probability of a drop which will travel all possible paths \( Si \) to the outlet.

\( \text{Pr} \, \text{ob}(T_{Si}) \) is the probability density function of the total path travel time \( T_{Si} \),
Erosion, sediment: the simplified process model for sediment yield

(Hartley, 1987a, 1987b; León, et al., 2001)
MODEL DEVELOPMENT

Nutrient loadings: Loading functions


\[
LD_{kt} = 0.1 C_d k_t Q_{kt} T D_k \\
LS_{kt} = 0.001 C_s k_t X_{kt} T S_k
\]

(Knisel, et al., 1993)
MODEL DEVELOPMENT

Flow routing
(Chu, et al., 2008)

Assumption:
Pollutant loads/concentration are conservative along the river reaches during storm events

\[
\frac{dSR(i, j, t)}{dt} = PS(i, j, t) + \frac{OC(ci, t)}{n(i)} + or(i, j-1, t) - or(i, j, t)
\]
RESULTS

Flow discharge

Suspended solid

P-PO4

N-NO3
MODEL UNCERTAINTY

Sensitivity analysis

Changes of total volume (%) vs Perturbation (%)

- CN
- Rain
- Vo
- Vs
- D (K)
- D50
- POR
- V
Monte-Carlo simulation

<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Description</th>
<th>pdf</th>
<th>Calibrated values</th>
<th>(min: max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>Curve Number</td>
<td>uniform</td>
<td>54</td>
<td>(52.56)</td>
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<tr>
<td>Rain</td>
<td>Rainfall (mm)</td>
<td>uniform</td>
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<td>(38.42)</td>
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<td>Vs</td>
<td>Overlandflow velocity (GIUH module)</td>
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<td>(0.03-0.05)</td>
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<tr>
<td>Vs</td>
<td>Average stream velocity (GIUH module)</td>
<td>uniform</td>
<td>0.75</td>
<td>(0.65-0.8)</td>
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<tr>
<td>D (K)</td>
<td>Soil erodibility factor</td>
<td>uniform</td>
<td>0.14</td>
<td>(0.1-0.18)</td>
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<tr>
<td>D50</td>
<td>Median size of soil particle</td>
<td>uniform</td>
<td>0.11</td>
<td>(0.05-0.15)</td>
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<tr>
<td>POF</td>
<td>Poprosity of surface soil layer</td>
<td>uniform</td>
<td>0.6</td>
<td>(0.5-0.7)</td>
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<td>Cdekt (NO₃)</td>
<td>N-NO₃ concentrations in dissolved forms</td>
<td>uniform</td>
<td>0.08(*)</td>
<td>(0.02-0.3)</td>
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<tr>
<td>Cdekt (P-PO₄)</td>
<td>P-PO₄ concentrations in solid-phase forms</td>
<td>uniform</td>
<td>1(*)</td>
<td>(1.5)</td>
</tr>
<tr>
<td>Cdekt (N-NH₄)</td>
<td>N-NH₄ concentrations in solid-phase forms</td>
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<td>0.2(*)</td>
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<td>V</td>
<td>River reach velocity (Flow routing module)</td>
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<td>0.8</td>
<td>(0.75-0.85)</td>
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<tr>
<td>TSS</td>
<td>TSS point sources (hourly)</td>
<td>uniform</td>
<td>50</td>
<td>(30-100)</td>
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<tr>
<td>P-PO₄</td>
<td>P-PO₄ point sources (hourly)</td>
<td>uniform</td>
<td>0.8</td>
<td>(0.5-1)</td>
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<td>N-NH₄</td>
<td>N-NH₄ point sources (hourly)</td>
<td>uniform</td>
<td>0.6</td>
<td>(0.4-1)</td>
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<tr>
<td>N-NO₃</td>
<td>N-NO₃ point sources (hourly)</td>
<td>uniform</td>
<td>1.2</td>
<td>(0.6-1.5)</td>
</tr>
</tbody>
</table>

(*) multiply factor for each land use

Suspended solid P-PO₄
CONCLUSIONS

• Non-point sources are significant pollution contributions to surface water in Vietnam
• A robust modelling framework has been developed and tested
• Uncertainty sources
• Integrating model algorithms in GIS environments
• Improving monitoring data to reduce uncertainty
• Model-based water quality management at catchment scale
• Adaptive water quality management
Thank you for your attention