On the use of SWAT for the identification of the most cost-effective nitrogen abatement measures for river basins

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Towards river basin management plans

- High environmental concerns
- Limited financial resources

- ‘Good’ water status to be reached by 2015
  - Set by EU Water Framework Directive (WFD)
  - Objectives to be reached at lowest cost
  - Set of actions; pollution abatement measures

- My research: Methodology to reach the water quality objectives at lowest cost
Need for modelling?

- Pollution abatement measures applied randomly
- Worst polluters targeted first
- No evidence that measures will achieve environmental targets
- Complexity ↑ when subbasin area ↑

- SWAT for impact on in-stream water quality
- Economic tool to select cheapest combination of measures
- Coupling SWAT-Economic tool
Methodology

- Identify pollution abatement measures
- Assess abatement potential for each measure
  - SWAT
  - Quantify impact on in-stream water quality
- Assess costs of each measure
- Annualize cost data (€/year)

Combine all measures into 1 database (€/kgN abatement/year)

Economic optimization

Results:
- Is good water quality achieved?
- Most cost-effective set of measures
- Cumulative cost of measures

Load reduction target
Economic optimization: Cost-Effectiveness

- Cost-minimization as objective function
- When environmental target is fixed
- ‘Benefits’ = pollution load reduction (kgN reduction)
- Few cost & effect data available (at basin scale)
Impact on water quality in SWAT2005

Needed

- Calibration of a water quality model
- Determine immission coefficients $\alpha$
- Run scenario’s of pollution abatement measures

$\rightarrow$ Pre- and Postprocessing tools needed for SWAT2005

**immission coefficient**

$$\alpha = \frac{\text{load that reaches the control section}}{\text{load emitted at the source of the pollution}}$$
Pre- and postprocessing tool for SWAT2005

- Make input files for water quality modelling
  - MGT files for fertilizer application
  - Point source pollution files
- Read-in SWAT2005 output
- Plot graphs for flow and water quality parameters
- Calculate objective functions
  - such as BIAS, $R^2$, SSQ, NSE
- Calculate average daily load

- **Excel tool**: easy to use, user-friendly interface
- **Matlab tool**: can be automated AND linked to economic tool
Excel tool for SWAT2005
Link SWAT2005 – Matlab – Economic tool

- **Run SWAT**
  - Read-in SWAT output
  - Immission coefficient, $\alpha$
  - Load reduction target, LR

- **Database of measures**
- **Read-in**
- **MATLAB®**
- **Economic optimization**
  - If $L_{new} > 0$, then adjust LR
    - Use $\alpha_{new}$
  - Most cost-effective Set of measures
  - Run measures as scenario in SWAT
  - Calculate $L_{R_{new}}$ and $\alpha_{new}$

- **Good water quality achieved**
- **If $L_{R_{new}} \leq 0$**
Case study: Nete river basin in Belgium (1)

- Subbasin of Scheldt River
- 405 km²; 200,000 (500 inh/km²)
- Slopes < 2%
- Intensive industry
- Dairy production
Methodology

Identify pollution abatement measures

Assess abatement potential for each measure

Assess costs of each measure

SWAT

Quantify impact on in-stream water quality

Annualize cost data (€/year)

Combine all measures into 1 database (€/kgN abatement/year)

Economic optimization

Load reduction target

Results:
• Is good water quality achieved?
• Most cost-effective set of measures
• Cumulative cost of measures
Case Study: Results from CEA (4)
1) CE ratios

CE = Cost / Effectiveness
(in x € /kgN abatement)

<table>
<thead>
<tr>
<th>measure</th>
<th>CE ratio</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connect to WWTP*</td>
<td>52.8</td>
<td>3</td>
</tr>
<tr>
<td>reduce pigs</td>
<td>11.8</td>
<td>2</td>
</tr>
<tr>
<td>manure processing</td>
<td>9.6</td>
<td>1</td>
</tr>
</tbody>
</table>

* Cost of WWTP itself ~ 9 Euro/kg N
Case Study: Results from CEA (5)
2) Location and selection of abatement actions

<table>
<thead>
<tr>
<th>Subbasin</th>
<th>Best measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 manure processing</td>
</tr>
<tr>
<td>2</td>
<td>3 manure processing</td>
</tr>
<tr>
<td>3</td>
<td>2 manure processing</td>
</tr>
<tr>
<td>4</td>
<td>2 manure processing</td>
</tr>
<tr>
<td>Total cost</td>
<td>720 000 Euro/year</td>
</tr>
</tbody>
</table>
Link SWAT2005 – Matlab – Economic tool

**Run SWAT**
- Read-in SWAT output
- Immission coefficient, $\alpha$
- Load reduction target, LR

**Database of measures**

**Read-in**

**MATLAB®**

**Economic optimization**

- Most cost-effective Set of measures
- Run measures as scenario in SWAT
- Calculate $LR_{new}$ and $\alpha_{new}$

**If $L_{new} > 0$, then adjust LR use $\alpha_{new}$**

**If $LR_{new} \leq 0$**

**Good water quality achieved**
Case Study: Results from CEA (6)
Good water quality reached: NO

LR = 360 ton N/year
(6 times higher)
Conclusion

- Economic tool for SWAT2005 developed
- Pre- and postprocessing tools developed for SWAT2005 in Excel and in Matlab
- For water quality modelling

- Better load reduction target needed
- Optimization technique needed
- For each subbasin: load reduction target and immission coefficient
- Cost and effectiveness values uncertain