EU-Project MoNit: Prognosis of future nitrate input into the Upper Rhine Valley aquifer

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MoNit: project partners from CH, D, F
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"Modelling the Nitrate load of the Upper Rhine Valley aquifer system"
There was a urgent need for a transnational planning & prognosis instrument

MoNit

The answer:

Within MoNit a transnational prognosis instrument has been developed.

It allows to assess the effects of a changing political (e.g. Common Agricultural Policy – CAP - of the European Union), technical and climatic framework on the nitrate load
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29.-31.1.2007
MMM-Graz

Groundwater model

accounts for:

- groundwater recharge
- surface water
- groundwater flow
- nitrate transport
- socio-economic factors

Integrated modelling concept

- Groundwater model
- Nitrate model
- Socio-economic model
- Integrated modelling system

Introduction – Modelling system – Results & sources of error - Conclusion
Introduction – Modelling system – Results & sources of error - Conclusion

Landuse (2000) (Landsat-TM)

Upper Rhine aquifer = groundwater model (→ 4300 km²)

Introduction – Modelling system – Results & sources of error - Conclusion

Groundwater model: spatial discretisation

- 2 Aquifers
- partially 1 Aquiclude
- 10 model layers
- 100 m grid size

MODFLOW + STREAM + MT3D
2000 (mod.) (+LAKE)

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Socio-economic model

- product prices
  - input factors

agricultural activities

Common Agricultural Policy (CAP)

- economical model (linear programming)
  - maximisation of income under constraints

cropping pattern (soil occupation)
Nitrate input and transfer

Introduction – Modelling system – Results & sources of error - Conclusion

Plant growth model (STICS) (plot/field scale)

- prognosis of crop harvest + nitrate leaching
- depending on soil type, climatic variations and cultivation methods
Interface to groundwater model

Nitrate balance model

STOFFBILANZ\textsuperscript{1} covers
- area of the groundwater model (blue)
- Neighboring catchments

Its output is used as input to the groundwater model

\textsuperscript{1} cf. contribution of M. Gebel et al. at MMM

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Selected results and sources of error
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**simulation of scenarios & options for action**

**definition of 3 scenarios**


**Scenario A1:** “high liberalization of markets”

and

**Scenario B2:** “growing energy costs” \(\rightarrow\) strong extension of bio energy sector

plus

**Tendency Scenario:** most plausible scenario (by experts)

**compared to base run**
(no changes 2000-2050)
socio-economic modelling

changes in soil occupation

<table>
<thead>
<tr>
<th>Changes [% soil occupation]</th>
<th>T</th>
<th>A1</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>KM</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>SG</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>WW</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
</tr>
</tbody>
</table>

France

Germany

Source of error: socio-economic model type

Linear model / equilibrium:
small differences in income may cause large changes in soil occupation

→ not always realistic, farmers are “conservative”
prognosis of nitrate concentration

area [ha] with nitrate conc. > 50mg/l

Mean value [mg/l]

<table>
<thead>
<tr>
<th>Year</th>
<th>Area exceeding threshold [ha]</th>
<th>Mean value [mg/l]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>18,000</td>
<td>10,000</td>
</tr>
<tr>
<td>2015</td>
<td>14,000</td>
<td>8,000</td>
</tr>
<tr>
<td>2025</td>
<td>10,000</td>
<td>6,000</td>
</tr>
<tr>
<td>2035</td>
<td>6,000</td>
<td>4,000</td>
</tr>
<tr>
<td>2045</td>
<td>2,000</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**Source of error: spatial scale**

**Reason:**

1980-2005
spatial resolution: community level

2005-2050: agricultural regions

→ smoothing of input data
→ elimination of hot spots
therefore: Change detection only on regional + country level

T – Tendency scenario
Scenario A1
Scenario B2

13 agricultural regions

mean (country)

 Änderung gegenüber Referenz 2003 [%] / Modification par rapport à la référence 2003 [%]

T→0

groundwater model

contributions (surface water / ground water)

STREAM
surface water

MODEFLOW
groundwater-flow model

MT3D
transport of nitrates

hydrogeological model

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Independent model validation

Water balance of River Rhine: Basel - Maxau

- \( \Delta Q \) (Maxau – Basel) = 210 m\(^3\)/s measured
- \( \Delta Q \) (Maxau – Basel) = 231 m\(^3\)/s simulated
- **Error**: +21 m\(^3\)/s (10%)

> **Reasons**: (1) wrong rainfall distribution
> (2) underestimation of evapotranspiration
> (e.g. on irrigated land)
selected nitrate concentrations (1986-2003)

Introduction – Modelling system – Results & sources of error - Conclusion

measured
simulated

development of nitrate concentration 1950-2005
modelled vs. measured

→ partially wrong estimation of nitrate input for 1990-2000
development of nitrate concentration 1950-2005
modelled vs. measured

France

Germany

simulated recession too fast

Additional runs: development of nitrate storage 2005-2050

S3: no changes since 1980
S4: no changes since 1990 → +/- equilibrium
E: no changes since 2000 (“base run”)
If input constant since 1990...

If input constant since 1980...

proves the urgent need for nitrate reduction in the 1980s!
Plant growth model STICS
Source of error: Incomplete process representation

On soils with high stone content, systematic underestimation of harvest²

²cf. Poster contribution of A. Heuer and M. Casper
Source of error:
Incomplete process representation

Unsaturated zone
- delay: function of distance to groundwater table & grain size
- no decay of nitrates!

But:
decay of nitrates is simulated as a regionally calibrated linear function of $O_2$ concentration

Introduction – Modelling system – Results & sources of error - Conclusion

Conclusion
- The modelling system is able to reproduce the long term behavior of the real system.
- The simulated fast recession of nitrate concentrations can not be validated for all measured locations (D/F).
- Different sources of error/uncertainty could be detected:
  - high sensitivity to small fluctuations in marked prices of the socio-economical model
  - differences in temporal and spatial scales of submodels
  - errors in input data (groundwater recharge + real amount of fertilizer application)
  - incomplete process representation

- Monitoring of Nitrates still necessary to prove reduction
- A permanent trans-national collaboration should be implemented
final reports (5 books!) available for free through:
Bibliothek, LUBW, Griesbachstr. 1
D-76185 Karlsruhe/Germany
(bibliothek@lubw.bwl.de)

http://monit.server.de

Thank you for your kind attendance!